XXIV. *An Account of the Meaſurement of a Baſe on* Hounſlow-Heath. *By Major-General* William Roy, *F.R.S. and A.S.*

Read from April 21 to June 16, 1785.

INTRODUCTION.

ACCURATE ſurveys of a country are univerſally admitted to be works of great public utility, as affording the ſureſt foundation for almoſt every kind of internal improvement in time of peace, and the beſt means of forming judicious plans of defence againſt the invaſions of an enemy in time of war, in which laſt circumſtances their importance uſually becomes the moſt apparent. Hence it happens, that if a country has not actually been ſurveyed, or is but little known, a ſtate of warfare generally produces the firſt improvements in its geography: for in the various movements of armies in the field, eſpecially if the theatre of war be extenſive, each individual officer has repeated opportunities of contributing, according to his ſituation, more or leſs towards its perfection; and theſe obſervations being ultimately collected, a map is ſent forth into the world, conſiderably improved indeed, but which, being ſtill defective, points out the neceſſity of ſomething more accurate being undertaken, when times and circumſtances may favour the deſign.

The riſe and progreſs of the rebellion which broke out in the Highlands of Scotland in 1745, and which was finally ſuppreſſed,

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preſſed, by his Royal Highneſs the late Duke of Cumberland, at the battle of Culloden in the following year, convinced Government of what infinite importance it would be to the State, that a country, ſo very inacceſſible by nature, ſhould be thoroughly explored and laid open, by eſtabliſhing military poſts in its inmoſt receſſes, and carrying roads of communication to its remoteſt parts. With a view to the commencement of arrangements of this ſort, a body of infantry was encamped at Fort Auguſtus in 1747, under the command of the late Lord BLAKENEY, at that time a Major-General; at which camp my much reſpected friend, the late Lieutenant-General WATSON, then Deputy Quarter-Maſter-General in North Britain, was officially employed. This officer, being himſelf an engineer, active and indefatigable, a zealous promoter of every uſeful undertaking, and the warm and ſteady friend of the induſtrious, firſt conceived the idea of making a map of the Highlands. As aſſiſtant Quarter-Maſter, it fell to my lot to begin, and afterwards to have a conſiderable ſhare in, the execution of that map; which being undertaken under the auſpices of the Duke of CUMBERLAND, and meant at firſt to be confined to the Highlands only, was nevertheleſs at laſt extended to the Lowlands; and thus made general in what related to the mainland of Scotland, the iſlands (excepting ſome leſſer ones near the coaſt) not having been ſurveyed.

Although this work, which is ſtill in manuſcript, and in an unfiniſhed ſtate, poſſeſſes conſiderable merit, and perfectly anſwered the purpoſe for which it was originally intended; yet, having been carried on with inſtruments of the common, or even inferior kind, and the ſum annually allowed for it being inadequate to the execution of ſo great a deſign in the beſt manner, it is rather to be conſidered as a magnificent military ſketch, than a very accurate map of a country. It would, however, have been completed, and many of its imperfections no doubt remedied; but the breaking out of the war of 1755 prevented both, by furniſhing ſervice of other kinds for thoſe who had been employed upon it.

On the concluſion of the peace of 1763, it came for the firſt time under the conſideration of Government, to make a general ſurvey of the whole iſland at the public coſt. Towards the execution of this work, whereof the direction was to have been committed to my charge, the map of Scotland was to have been made ſubſervient, by extending the great triangles quite to the northern extremity of the iſland, and filling them in from the original map. Thus that imperfect work would have been effectually completed, and the nation would have reaped the benefit of what had been already done, at a very moderate extra-expence.

It will not be expected, that I ſhould here attempt to aſſign cauſes for the long delay that has taken place in carrying a work of ſo laudable a nature into execution: ſuffice it to ſay, that a period of twelve years having elapſed, ſince the ſcheme had been firſt propoſed, as a work that could be beſt executed in time of profound peace, without any thing being done in it, previous to the nation's being unfortunately involved in the American war; it was ſufficiently obvious, that peace muſt be once more reſtored, before any new effort could be made for that purpoſe. In the mean while, as I ſtill entertained hopes that a work which ſeemed to merit the attention of the public, would, at ſome future period, be begun, and, by gradual perſeverance, ultimately brought to perfection; therefore, in the courſe of my ordinary military employments, wherein the very beſt opportunities have offered of acquiring a thorough knowledge of the country, I have not failed to obſerve, at leaſt in a general way, ſuch ſituations as ſeemed to be the beſt adapted for the meaſurement of the baſes that would be neceſſary for the formation of the great triangles, and connecting the different ſerieſes of them together.

The peace of 1783 being concluded, and official buſineſs having detained me in or near town during the whole of that ſummer, I embraced the opportunity, for my own private amuſement, to meaſure a baſe of 7744.3 feet, acroſs the fields between the Jews-Harp, near Marybone, and Black-Lane, near Pancras; as a foundation for a ſeries of triangles, carried on at the ſame time, for determining the relative ſituations of the moſt remarkable ſteeples, and other places, in and about the Capital, with regard to each other, and the Royal Obſervatory at Greenwich. The principal object I had here in view (beſides that it might poſſibly ſerve as a hint to the public, for the revival of the now almoſt forgotten ſcheme of 1763) was, to facilitate the compariſon of the obſervations, made by the lovers of aſtronomy, within the limits of the projected ſurvey; namely, Richmond and Harrow, on the weſt; and Shooter's-Hill and Wanſted, on the eaſt: and thinking, that a Paper, containing the reſult of theſe trigonometrical operations, might not prove unacceptable to the Royal Society, I was engaged in making the computations for that purpoſe, when, very unexpectedly, I found, that an operation of the ſame nature, but much more important in its object, was really in agitation. This I ſaw would ſuperſede, at leaſt for the preſent, my own private obſervations, and perhaps render them wholly uſeleſs, unleſs it were as a matter of mere curioſity hereafter, to ſee how far ſuch as depended on a ſhort baſe, and a ſmall inſtrument (a quadrant of a foot radius) would agree with

thoſe

thoſe founded on a much longer baſe, and angles determined by a large circular inſtrument, being that propoſed, as the beſt that could be made uſe of in the operation now to be mentioned.

In the beginning of October, 1783, Comte D'ADHEMAR, the French Ambaſſador, tranſmitted to Mr. FOX, then one of his Majeſty's principal Secretaries of State, a Memoir of M. CASSINI DE THURY, in which he ſets forth the great advantage that would accrue to aſtronomy, by carrying a ſeries of triangles from the neighbourhood of London to Dover, there to be connected with thoſe already executed in France, by which combined operations the relative ſituations of the two moſt famous obſervatories in Europe, Greenwich and Paris, would be more accurately aſcertained than they are at preſent *.

This Memoir the Secretary of State, by his Majeſty's command, tranſmitted to Sir JOSEPH BANKS, the very reſpectable and worthy Preſident of the Royal Society; who, about the middle of November, was pleaſed to communicate it to me, propoſing at the ſame time, that I ſhould, on the part of the Society, charge myſelf with the execution of the operation. To this propoſition I readily aſſented, on being ſoon afterwards aſſured, through the proper official channels, that my undertaking it met with his Majeſty's moſt gracious approbation.

A generous and beneficent Monarch, whoſe knowledge and love of the ſciences are ſufficiently evinced by the protection which HE conſtantly affords them, and under whoſe auſpices they are ſeen daily to flouriſh, ſoon ſupplied the funds that were judged neceſſary. What his Majeſty has been pleaſed to

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* M. CASSINI's Memoir, with the Aſtronomer Royal's remarks on what is therein alledged, concerning the uncertainty of the relative ſituations of the two Obſervatories, will be given in the ſequel.

give ſo liberally, it is our duty to manage with proper and becoming frugality, conſiſtent with the beſt poſſible execution of the buſineſs to be done, ſo as to make it redound to the credit of the Nation in general, and of this Society in particular.

The operation, whereof we are now to give ſome account, being the firſt of the kind, on any extenſive ſcale, ever undertaken in this country, naturally enough ſub-divides itſelf into two parts. Firſt, the choice and meaſurement of the baſe, with every poſſible care and attention, as the foundation of the work; ſecondly, the diſpoſition of the triangles, whereby the baſe is to be connected with ſuch parts of the coaſt of this iſland as are neareſt to the coaſt of France, and the determination of their angles, by means of the beſt inſtrument that can be obtained for the purpoſe, from which the reſult or concluſion will be drawn. It is the firſt part only, as a ſubject of itſelf ſufficiently diſtinct, that we are now to lay before the Society; it having been judged more adviſable, to ſhew that no time has been loſt in making reaſonable progreſs, than to defer the account till the whole operation ſhould be ultimately completed.

Choice of the Baſe. Tab. XVI.

Hounſlow-Heath having always appeared to be one of the moſt eligible ſituations, for any general purpoſe of the ſort now under conſideration, becauſe of its vicinity to the Capital and Royal Obſervatory at Greenwich, its great extent, and the extraordinary levelneſs of its ſurface, without any local obſtructions whatever to render the meaſurement difficult; being likewiſe commodiouſly ſituated for any future operations of a ſimilar nature, which his Majeſty may pleaſe to order to be extended from thence, in different directions, to the more remote parts of the iſland, it was propoſed to Sir JOSEPH BANKS, that the local circumſtances ſhould be actually examined; ſo far, at leaſt, as to enable us to form ſome judgement, of the beſt poſition of the line to be meaſured.

The 16th day of April, 1784, being accordingly fixed on for the purpoſe, and Mr. CAVENDISH and Dr. BLAGDEN accompanying the Preſident on this occaſion, we began our obſervations at a place called King's Arbour, at the north-weſt extremity of the Heath, between Cranford-Bridge and Longford; and having proceeded from thence through the narrow gorge, formed by Hanworth-Park and Hanworth-Farm, we finiſhed at Hampton Poor-houſe, near the ſide of Buſhy-Park, at the ſouth-eaſt extremity; the total diſtance, from the ſurvey of Middleſex, being upwards of five miles.

On this inſpection it was immediately perceived, that the firſt part of the operation, in order to facilitate the meaſurement, would be, the clearing from furze-buſhes and ant-hills, a narrow tract along the heath, as ſoon as the ground ſhould be ſufficiently dry to permit the baſe to be accurately traced out thereon.

Firſt tracing of the Baſe, and clearing of the Ground. Tab. XVI.

Chiefly with a view to the more effectual execution of the work, it was judged to be a right meaſure to obtain and employ ſoldiers, inſtead of country labourers, in tracing the baſe, clearing the ground, and aſſiſting in the ſubſequent operations. For, at the ſame time that this was obviouſly the moſt frugal method, it was evident, that ſoldiers would be more attentive to orders than country labourers; and by encamping on the ſpot would furniſh the neceſſary centinels, particularly during the night, for guarding ſuch parts of the apparatus, as it was foreſeen muſt remain carefully untouched, in the frequent interims of diſcontinuing and reſuming the work. Accordingly, a party of the 12th regiment of foot, conſiſting of a ſerjeant, corporal, and 10 men, were ordered to march from Windſor to Hounſlow-Heath, where they encamped on the 26th of May, cloſe by Hanworth Summer-houſe, to which ſpot the neceſſary tents, camp equipage, and entrenching tools, &c. had been previouſly ſent.

Whatever might have been the particular direction given to the baſe conſidered by its extremities, from conſulting the plan it will eaſily appear, that it muſt always neceſſarily lead through the narrow gorge of the Heath formed by Hanworth-Park and Hanworth-Farm. The firſt point therefore to be attended to, in tracing it out, was, that it might lead through this paſs, without interfering with certain ponds, or gravel-pits full of water, which are in it. Theſe were eaſily avoided by carrying the line pretty near to Hanworth Summer-houſe; and in directing the teleſcope from thence towards the ſouth-eaſt, it was accidentally found, that by leaving Hampton Poor-houſe a very little to the weſtward, or right, the line would coincide with a remarkable high ſpire, ſeen at the diſtance of eleven or twelve miles, and known afterwards to be Banſted-Church. As there could not be a better ſituated, or more conſpicuous object than this, therefore the firſt or ſouth-eaſt ſection of the baſe, comprehended between the Summer-houſe and the angle of the ſmall field adjoining to Hampton Poor-houſe, was immediately directed upon it; and the ſoldiers were the ſame day ſet to work to clear the tract, which, at a medium, was made from two to three yards in breadth. This operation continued eight or ten days, owing to the lower part of the heath, between Wolſey-River and the Poor-houſe, being encumbered with bruſh-wood.

When the clearing of the firſt ſection was completed, the ſecond, comprehended between the Summer-houſe and the great road leading from Staines to London, was traced out in the following manner. One of the pyramidal bell-tents (whereof two had been provided, one of twenty-five, and the other of fifteen feet in height) being placed at the ſtation near the Summer-houſe, camp colours were then arranged from diſtance to diſtance, ſo as to be in a line with the bell-tent and Banſted ſpire. In like manner, the third ſection, comprehended between the Staines Road and King's Arbour, was traced out.

This firſt tracing of the baſe was done by means of a common teleſcope held in the hand only, that no time might be loſt in employing the ſoldiers to ſmooth the tract which was to be meaſured; becauſe the tranſit inſtrument (my own property, for which a portable ſtand had been for ſome time preparing) was not yet ready to be applied, as it afterwards was, in tracing out the baſe more accurately.

The camp ſtill remained, where it was originally pitched, at the angle of Hanworth-Park, this being a very convenient poſition, with regard to the firſt and ſecond ſections; but being too remote from the third, that time might not be loſt, and the men unneceſſarily fatigued in marching backwards and forwards; therefore, one half of the party, under the command of the corporal, was detached to the northward, and quartered in the neighbouring villages, to clear the third ſection, while the ſerjeant, with the remainder, were occupied in ſmoothing the ſecond. Owing to the extraordinary wetneſs of the ſeaſon, this operation required more time than had been at firſt imagined, not having been entirely finiſhed before the firſt week of July. We ſhall therefore leave it going on, and in the mean time proceed to deſcribe the inſtruments that were ſubſequently made uſe of in the firſt and ſecond meaſurements.

Steel Chain. Tab. XVII.

One of the firſt inſtruments, which that able artiſt Mr. RAMSDEN had orders to prepare, was a ſteel chain, one hundred feet in length, the beſt that he could make. Not that it was intended, nor could it be ſuppoſed, that we ſhould abſolutely abide by the reſult that this chain ſhould furniſh us with, for the length of the baſe; but it was hoped, that an inſtrument of this ſort might be made, which would meaſure diſtances much more accurately than any thing of that kind had ever done before: and it was conſidered as an object of ſome conſequence, to endeavour to ſimplify, and render as eaſy as poſſible, the meaſurement of baſes in future: an operation which, hitherto, has always been found to be tedious and troubleſome, to which we may now further add, uncertain likewiſe, when done with rods of deal, as will appear from the account hereafter to be given.

The conſtruction of the chain, which is on the principles of that of a watch, will be underſtood from the repreſentation of ſome of its chief parts, to the full ſize, in tab. XVII. where the firſt, or zero-end link, is ſhewn both in plan and elevation, in the ſtate in which it was originally applied to meaſurement on the ſurface of the ground. Each link conſiſts of three principal parts; namely, a long plate; two ſhort ones, half the thickneſs of the former, with circular holes near the

extremities

extremities of each; and two caſt-ſteel pins, or axes, ſuited to the diameters of the holes, which ſerve to connect the adjoining links together. The holes in the ſhort plates are made rough or jagged with a file; ſo that when they have embraced the ends of two adjoining long ones, and the pins have paſſed through all the holes, in rivetting their extremities, they are made perfectly faſt, and as it were united to the ſhort plates; while the embraced ends of the long ones turn freely round on the middle part of the pins.

At every tenth link the joint, juſt now deſcribed, has a poſition at right-angles to the former; that is to ſay, the ſhort plates lie here horizontally, and the pins paſſing through them ſtand vertically. Thus, there being in the whole chain two hundred caſt-ſteel pins, one hundred and eighty lie horizontally; and twenty, including the two by which the handles are attached, ſtand vertically. Theſe croſs-joints, which were chiefly intended that the chain might fold up in a ſmaller compaſs, by returning upon itſelf at every tenth link, are likewiſe uſeful in preſenting a horizontal ſurface, to which ſmall circular pieces of braſs are ſcrewed, with figures 1, 2, 3, &c. to 9, engraved on them, denoting the decimal parts of the length. Thus the middle croſs-joint, or that which ſeparates the 50th from the 51ſt link, is ſhewn in the Plate with the figure 5 upon it.

The chain, in its firſt conſtruction (for we are now to point out ſome alterations that were afterwards made in it), was one hundred feet in length, including the two braſs handles; in the extremity of each of which there was a ſemi-circular hole, of the ſame diameter with the ſteel arrows ſucceſſively fixed in the ground, and ſerving to keep the account of the number of chains, when applied to common meaſurement. In this its firſt mode of application it was ſoon diſcovered, as we ſhall have occaſion to mention hereafter, how admirably the chain performed; and that, with ſome farther precautions, a ſtill greater degree of exactneſs might be attained, by ſupporting it on ſtands, or even on planks, laid on, or but little removed from, the common ſurface of the earth. For this purpoſe, the two end-links were altered, each being now made equal to one foot, excluſive of the handles. By referring to tab. XVII. the nature of this alteration will be eaſily conceived. It conſiſted in ſcrewing to the under ſide of the handles, very near the joints, two feather-edged pieces of braſs *; the one denoting zero, and the other 100 feet. Over the dart at the firſt, a plummet with a fine ſilver wire being ſuſpended, that wire, by a very ſimple apparatus, hereafter to be deſcribed, may be brought accurately to coincide with any point whatever of commencement: and at the ſecond, a fine line with a knife, or other ſharp inſtrument, being drawn on a piece of card placed there for the purpoſe, and changed as often as needful; or, as was likewiſe practiſed, and found to anſwer better, a line on a moveable ſlide of braſs, attached to the top of the ſtand or plank, being brought to coincide with the feather-edge, and then faſtened underneath; the extremity of the 100 feet is readily aſcertained: and thus the meaſurement may be continued on with great accuracy to any diſtance at pleaſure.

That the chain, in this its altered ſtate, may ſtill be advantageouſly applied to ordinary meaſurement on the ſurface of the earth, the pieces above deſcribed, having ſteady pins, and being faſtened with ſcrews, can be eaſily removed, and others,

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* They were originally of braſs, but are now of ſteel, that the edges by being harder might run leſs riſk of being damaged.

exactly of the ſame length, ſubſtituted in their ſtead, with ſemi-circular holes (as repreſented in the Plate by dotted lines near the joint of the handle) to receive the ſteel arrows, then to be made uſe of in the manner already mentioned.

This moſt excellent chain ſeems not to have ſuffered any perceptible extenſion from the uſe that has hitherto been made of it. It is ſo accurately conſtructed, that when ſtretched out on the ground, as in common uſe, all the long plates lying vertically or edge-wiſe, if a perſon, laying hold of either end with both hands, gives it a flip or jerk, the motion is, in a few ſeconds, communicated to the other end, in a beautiful vertical ſerpentine line; when the perſon, holding that handle, receives a ſudden ſhock, by the weight of the chain pulling him forcibly. The chain weighs about eighteen pounds, and when folded up is eaſily contained in a deal box, about fourteen inches long, eight inches broad, and the ſame in depth.

Deal Rods. Tab. XVIII.

The baſes which have hitherto been meaſured in different countries, with the greateſt appearance of care and exactneſs, have all, or for the moſt part, been done with deal rods of one kind or other, whoſe lengths being originally aſcertained by means of ſome metal ſtandard, were, in the ſubſequent applications of them, corrected by the ſame ſtandard. Having thus had ſo many precedents, ſerving as examples to guide us in our choice, it was natural enough that we ſhould purſue the ſame method in the meaſurement to be executed on Hounſlow-Heath; taking, however, all imaginable care, that our rods ſhould be made of the very beſt materials that could be procured;

cured; with this farther precaution, that by truſſing them, they ſhould be rendered perfectly inflexible, a circumſtance not before attended to.

As ſome difficulty had been found in procuring well-ſeaſoned Pine-wood of ſufficient length, and perfectly free from knots, for the intended purpoſe; therefore Sir Joseph Banks had early applied to the Admiralty for aſſiſtance in this reſpect; and forthwith obtained an order to be furniſhed with what we might have occaſion for, from his Majeſty's yard at Deptford, where an old New-England maſt, and alſo one of Riga wood, were ſpeedily cut up for our uſe.

New-England white Pine is lighter, leſs liable to warp, and leſs affected by moiſture, than Riga red wood. But the New-England maſt, when it came to be very minutely examined, was found to be too much wounded by ſhot-holes in ſome parts, or too much decayed or knotty in others, to afford us a ſufficiency. This being the caſe we had recourſe to the Riga wood, which was indeed extremely ſmooth and beautiful; and ſo perfectly ſtraight-grained, that a fibre of it, when lifted up, might be drawn, like a thread, almoſt from one end to the other.

It had been in contemplation, to make the rods of twenty-five or thirty feet in length; and one of the former dimenſions was actually conſtructed: but this being found to be rather too unwieldy, it was judged beſt to content ourſelves with thoſe of about twenty feet.

Different opinions have been entertained with regard to the beſt mode of applying rods in meaſurement; ſome contending that contacts, or that of butting the end of one rod againſt the end of the other, is the beſt; while others (with more probability of being right) are of opinion, that the adjuſtment by the coincidences of lines ſhould have the preference. The firſt is undoubtedly the moſt expeditious method; but ſeems at the ſame time to be liable to this very objectionable circumſtance, that the probable errors fall all one way: whereas, in the ſecond method, although by far the moſt tedious, the errors of coincidence falling ſometimes on one ſide, and ſometimes on the other, they compenſate for, or deſtroy, each other; and therefore no error is committed.

With the view of ſatisfying both parties, and in order to put the matter, if poſſible, out of doubt, it was judged proper to conſtruct the rods in ſuch a manner as to admit of both methods being tried, that we might adhere to that which ſhould be found by experience to be the beſt.

Three meaſuring rods were accordingly ordered to be made, and alſo a ſtandard rod, with which the former were from time to time to be compared. Their general conſtruction will be better conceived from the plan and elevation, and other repreſentations of their principal parts, in tab. XVIII. than by any deſcription, however particular, conveyed in words. It will be ſufficient to ſay, that the ſtems of the three meaſuring rods are each twenty feet three inches in length, reckoning from the extremities of the bell-metal tippings; very near two inches deep; and about 1¼ inch broad. Being truſſed laterally and vertically, they are thereby rendered perfectly, or at leaſt as to ſenſe, inflexible. The ſtandard rod could only be truſſed laterally; and it is juſtly repreſented by the plan of the other rods, excepting that its ſtem is ſomething ſtronger, and that it has two or three inches at each end of extra-length, the reaſons for which differences will appear hereafter.

By referring to the Plate it will be obſerved, that two narrow pieces of ivory, each faſtened with two ſmall ſcrews, are inlaid into the upper ſurface of the rods, within one inch and a half of the extremities of the tippings. Theſe ivory pieces received the fine black lines cut into them when the lengths of the rods were laid off, in the manner hereafter to be mentioned, and accurately determined the intermediate diſtance of 20 feet, or 240 inches, the meaſure to be uſed in the application by coincidences: whereas, in that by contacts, the ſpace comprehended between the extremities of the projecting lips of the tippings, is 243 inches.

Immediately behind each ivory piece, a cavity is formed underneath, in the middle of the ſtem. This receives a braſs wheel, about eight-tenths of an inch in diameter, whoſe axis turns in the fork of a braſs ſpring, five inches long, faſtened by a ſcrew to the under ſurface juſt before the croſs feet. Theſe ſprings are only of ſuch ſtrength as to permit the wheels to be forced up into the cavities by the weight of the rod, which, in its adjuſted ſtate, always reſts entirely on the ſurfaces of the two ſtands that ſupport its extremities. But when the rod is to be raiſed from the ſtands, then the milled-headed ſcrews, projecting above the upper ſurface, and ſtanding over the middle of the ſprings, being brought to act, the wheels are thereby preſſed downwards, and receive the full weight of the rod, which is then eaſily moved backwards or forwards to its true poſition, either of contact or coincidence.

The croſs-feet, placed about 5½ inches from the ends of the rods, and 1¾ inch from the inſertion of the truſſings, are each about nine inches long, 1½ broad, and nearly an inch in depth, having their lower ſurfaces level with that of the ſtem. By

means

means of theſe, the rods are not only kept more ſteady on the ſtands, againſt the common action of the wind upon the truſſings; but they likewiſe ſerve as holds for the vertical and horizontal braſs clamps, whereby the rods are made faſt to the ſtands on one ſide or other, and in both modes of application, contacts and coincidences; as will be more fully explained hereafter, in deſcribing the tops of the ſtands.

Braſs Standard Scale, and method of laying off the lengths of the Deal Rods.

At the ſale of the inſtruments of the late ingenious optician Mr. JAMES SHORT, I purchaſed a finely divided braſs ſcale, of the length of 42 inches, with a VERNIER's diviſion of 100 at one end, and one of 50 at the other, whereby the 1000th part of an inch is very perceptible. It was originally the property of the late Mr. GRAHAM, the celebrated Watch-maker; has the name of JONATHAN SISSON engraved upon it; but is known to have been divided by the late Mr. BIRD, who then worked with SISSON.

It is ſufficiently well known to this Society, that their braſs ſtandard ſcale, about 42 inches long, which contains on it the length of the ſtandard yard from the Tower, that from the Exchequer, and alſo the French half-toiſe, together with the duplicate of the ſaid ſcale, ſent to Paris for the uſe of the Royal Academy of Sciences, were both made by Mr. JONATHAN SISSON, under Mr. GRAHAM's immediate direction. Now, although there ſeemed to be every reaſon to ſuppoſe, that the ſcale at preſent in my poſſeſſion, originally Mr. GRAham's property, would correſpond with thoſe above-mentioned, which he had been directed by the Royal Sociey, with ſo much care and pains, to provide; yet, that nothing of this ſort might remain doubtful, it was judged right, in ſettling the abſolute length of the baſe, which I meaſured near London in 1783, as has been mentioned in the introduction to this Paper, that the two ſcales ſhould be actually compared. Having accordingly obtained an order from the Preſident, for admiſſion into the Society's Apartments, I went there in the afternoon of the 13th of Auguſt, and laid both ſcales taken out of their caſes on the table of the meeting-room, with thermometers along-ſide of them, that they might acquire the ſame temperature. On the forenoon of the 15th of Auguſt the compariſon was made, with the aſſiſtance of Mr. Ramsden, who for that purpoſe carried along with him his curious beam-compaſſes, whoſe micrometer-ſcrew ſhews very perceptibly a motion of $\frac{1}{5000}$th part of an inch. Thus the extent of three feet, being carefully taken from the Society's ſtandard, and applied to my ſcale, it was found to reach exactly to 36 inches, the temperature being 65°. In like manner, the beam-compaſſes being applied to the length of the Exchequer yard, the extent was now found by the micrometer to overreach that yard by $\frac{69}{10000}$th, or nearly $\frac{7}{1000}$th parts of an inch.

Having thus ſhewn that my ſcale is accurately of the ſame length with the Society's ſtandard, it remains to point out the uſe that was made of it, for aſcertaining the lengths of the deal rods, intended for the operation on Hounſlow-Heath. In the firſt place, Mr. Ramsden prepared a beam-compaſs, ſufficient to take in twenty feet, truſſed in all reſpects like the meaſuring rods, but ſomething deeper, and fitted as uſual with proper points and micrometer. The ſtandard rod being now conſtructed was laid on the ſhop-board, ſtrongly framed for the purpoſe, and nearly level. To one ſide of it, at the diſtance of about twenty feet two inches from center to center, two ſtrong bell-metal cocks were firmly ſcrewed. Theſe cocks were about 2¼ inches in length, three-eighths in thickneſs, and roſe above the ſtem nearly two inches, ſo as to be on the ſame plane with the ſurface of the meaſuring rods, when placed upon it.

A large plank, cut from the New-England maſt, upwards of thirty feet long, nine or ten inches broad, and about three inches thick, being ſet edge-wiſe in the ſame room, on part of the ſtands now ready for the operation, was, in that poſition, planed perfectly ſmooth and ſtraight. A ſilver wire being then ſtretched very tight, along the middle of the plank, from one end to the other, ſix ſpaces of forty inches each were marked off by the ſide of the wire, at which points ſeven braſs pins, about one-tenth of an inch in diameter, were driven into the wood, and their tops poliſhed with the ſtone. During the whole of this operation, and that which followed, the thermometer, lying by the ſide of the braſs ſcale, continued ſteadily at or very near 63°.

A fine dot being now made on one of the extreme pins, and the ſilver wire being ſtretched over the dot, and as near as poſſible over the middle of the other pins, in which poſition it was made faſt; the extent of forty inches, taken with the utmoſt care from the braſs ſcale, was then marked off, by placing one point of the beam-compaſſes in the dot, and with the other deſcribing a ſhort faint arc on the ſurface of the ſecond pin. The beam being then removed, and one point placed in the interſection of the arc and wire, with the other point a dot was made on the third pin, under the middle of the wire. Upon this dot, as a center, a faint arc was next deſcribed on the ſame pin where the firſt had been traced. In this manner the ſix times forty inches were marked off, alternately with dots and arcs; a method found by Mr. RAMSDEN, in his practice, to be more accurate, than when dots only are made uſe of.

The exact length of twenty feet, thus obtained, was next taken between the points of the long beam-compaſſes, and transferred to the tops of the bell-metal cocks, placed, as has been already mentioned, on the ſide of the ſtandard rod, in ſuch manner as to leave more than one inch and a half of the ſaid cocks beyond or without the lines denoting the extent of the twenty feet. This being done, the meaſuring rods were ſucceſſively placed on the ſtandard, and their ſides applying cloſe to the cocks, the diſtance of twenty feet was readily transferred from them to the inlaid ivory pieces, on which fine lines were afterwards cut, by marks accurately made for that purpoſe.

With regard to the adjuſtment of the lips of the bell-metal tippings, which extend exactly one inch and a half beyond the ivory lines, ſo as to make the total length of the rod 243 inches, it is to be obſerved, that they terminate in flat curves of 3½ inches radius, paſſing through the inch and half points, to which they were cautiouſly ground down, that at firſt they might rather exceed than be defective in length. Any two of the rods, lying in the ſame plane, and alſo in the ſame ſtraight line, being brought into contact with each other; if of the true length, the ſpace in that poſition, comprehended between the two lines on the inlaid ivory pieces, muſt be exactly three inches. For the purpoſe of this adjuſtment, the extent of three inches was therefore taken from the braſs ſcale and cut upon the ſide of a detached piece of ivory; which being readily applied to the aforeſaid intermediate ſpace, the ſame was gradually reduced, by grinding the lips equally, till it exactly correſponded with that taken from the ſcale.

The three rods are numbered by a cypher on the ſurface of the metal at each end, 1.2; 3.4; 5.6; and that being the order in which they were to be applied in actual meaſurement, ſo it was likewiſe the order in which they were adjuſted; that is to ſay, the rod 1.2 was adjuſted with 3.4, and with 5.6; and the rod 3.4 was, in like manner, adjuſted with 1.2 and 5.6.

One of theſe deal rods, when finiſhed, was found to weigh twenty-four pounds. They were intended to be contained in two cheſts, one large and the other ſmaller. The large cheſt, which is about 2½ feet deep, may be called a double one, becauſe it has two lids that lift quite off, which, in turning upſide down, become alternately top and bottom, having between them, but much nearer to the one than the other, a bottom that is common to both. The ſhallow ſide holds the ſtandard rod; and the other, two of the meaſuring rods; which laſt is rendered practicable by having one of the ſide braces of each fixed only with ſcrews, ſo as to be removed and replaced at pleaſure. Thus one of the rods being laid in its place, the other is put over it in an inverted poſition; and both having the proper faſtenings to keep them in their poſitions, the lid is then put on, and fixed by ſcrews. The cheſt being now turned upſide down, and the other lid removed, the ſtandard is thereby diſcovered reſting on the common bottom, which has bands laid acroſs it for the purpoſe, a few inches below what has now become the ſurface of the cheſt. It was neceſſary that the ſtandard ſhould reſt thus high, both that the light might come freely upon it, and that, being ſupported by the deep ſides of the cheſt, it might be prevented from twiſting, for it will be remembered that it is only truſſed laterally. By means of a ſmall braſs ſpring fixed to each end of the ſtandard, a fine ſilk thread, as being leſs liable to accident than ſilver wire, is ſtretched along its ſtem, which by ſmall wedges prepared for the purpoſe, and ſlipped in between it and the bands on which it reſts, is always brought into the ſame poſition. This being done, the ſilk thread is turned off, ſo as to permit the meaſuring rods to be laid on the ſtandard for compariſon. With regard to the ſmaller cheſt, ſuch a one was actually made, and ſent down to the heath, towards the cloſe of the operation with the deal rods; but from ſome miſtake in its dimenſions, it would not admit the third rod.

Stands for the Meaſuring Rods. Tab. XVIII. and XIX.

From the extraordinary levelneſs of Hounſlow-Heath, the aſcent from the ſouth-eaſt towards the north-weſt being little more than one foot in a thouſand in the diſtance of five miles, it was eaſily ſeen, that the computed baſe-line, or that actually forming a curve parallel to the ſurface of the ſea, at that height above it, would fall ſo little ſhort of the hypothenuſal diſtance, meaſured on, or parallel to, the ſurface of the Heath, as ſcarcely to deſerve notice, had it not been thought neceſſary to ſhew, how much one end of the baſe was really higher than the other; and to convince the world, that in an operation of this ſort, where ſo much accuracy was expected, no pains were ſpared, nor the moſt trivial circumſtances neglected.

From the trouble and uncertainty attending the frequent uſe of plummets, eſpecially in windy weather, inſtead of meaſuring level or baſe lines, as has hitherto been cuſtomary (in which caſe it would have been neceſſary to make uſe of the plummet, or ſome ſuch contrivance, at every ſtep of aſcent or deſcent) it was judged to be a better method to meaſure hypothenuſes, and, having obtained the relative heights of the ſtations by the accurate application of the teleſcopic ſpirit-level, to compute the baſe lines. Thus it was propoſed, that the length of the baſe on Hounſlow-Heath ſhould be obtained by meaſuring a line through the air, drawn parallel to the common ſurface from ſtation to ſtation, in equal diſtances of 200 yards or 600 feet each, as repreſented in the figure at the top of tab. XVIII.

For this purpoſe, two kinds of ſtands were uſed; one whoſe height was fixed, to be placed at the beginning and end of each 200 yards; and the others, whoſe heights were moveable, that their ſurfaces might be brought more eaſily to coincide with the line paſſing through the air from one fixed ſtand to the other. The fixed ſtands in their firſt ſtate, repreſented by that towards the left-hand in the plate for the deal rods, were only two feet ſeven inches in height; but when the glaſs rods were afterwards uſed, they had an additional piece of ten inches faſtened to the top (as in the left-hand ſtand of tab. XIX.) which made their total height above the Heath, including the platform on which they ſtood, three feet and a half. They are tripods of white deal, whoſe legs extend about three feet from each other; and being braced diagonally, are mortoiſed at top into circles of the ſame ſort of wood. Over this circle, a ſquare table of about 11½ inches is fixed, compoſed of oak, and mahogany at top; but both taken together do not exceed 1¼ inch in thickneſs.

The nature of the moveable ſtands, whereof there were at laſt no fewer than ſeventeen provided, will be comprehended from the repreſentations of them towards the right-hand in tab. XVIII. and XIX. Their general conſtruction, in what regards the part of them which is fixed, differs not from that of the others, excepting that they were of different heights, from two feet to about two feet eight inches, ſo as better to ſuit the irregularities of the ground where it might be neceſſary to place them. In the middle of each of theſe, an hexagonal wooden pipe deſcends, from the top to within two or three inches of the bottom, where it is joined by a brace reaching from each leg. This pipe receives the common cheeſe preſs wooden ſcrew (having three ſides ſcrewed and three plane), to the top of which the ſquare table is attached. It is embraced by the circular nut, or winch with four handles, whereby the table is elevated or depreſſed at pleaſure; and being brought to its proper height, is there made perfectly faſt by means of the flat-headed iron ſcrew, which paſſing through one of the legs, preſſes an iron plate, fixed in the inſide of the pipe, againſt one of the plane ſides of the ſcrew.

In deſcribing the deal rods, there has already been occaſion to make mention of the vertical and horizontal clamps, whereby the croſs-feet are faſtened to the table on the top of the ſtand. The nature of theſe tables will be beſt underſtood by conſulting the two plans of them towards the right hand in tab. XVIII.; whereof one repreſents the two grooves fitted for the alternate reception of the horizontal clamp, according to the ſide on which the rod lies that is to be moved on into coincidence; and the other ſhews it actually in its place, with the clamp itſelf detached in elevation along-ſide of it. Thus from the plan it may be perceived, that the firſt, or adjuſted rod, lies towards the farther ſide of the table, and is there ſecured by the vertical clamp. The ſecond, or moveable rod, lies on the hither ſide, and therefore the horizontal clamp is placed in the farther groove, where it is firmly pinched by the nut underneath. The rod has been brought to coincidence by working with the two milled-headed ſcrews againſt the oppoſite ſides of the croſs foot. This apparatus, although perfectly good in theory, was found to be much too confined in its nature to anſwer well in practice, requiring the ſtands to be placed with a degree of preciſion, which could not be effected in the field without great loſs of time; and this was the real cauſe, as will be ſeen hereafter, that the meaſurement by coincidences with the deal rods was given up, and that by contacts adhered to.

Towards the left-hand of tab. XVIII. the plan of one of the ſquare tables is repreſented with the ends of the ſecond and third rods upon it in contact. In this operation it will be perceived, that only one croſs-foot of each rod could now reſt on and be clamped to the ſtand, the tables having been inadvertently cut too ſmall to admit of both; and although this has the appearance of imperfection, yet no inconveniency whatever was found to reſult from it in practice, experience having ſhewn, that the clamping of either end ſufficed to keep the rod ſteady. Along-ſide of the table, the vertical clamp, being that now ſolely made uſe of, is likewiſe repreſented in elevation.

On the face or exterior ſide of each leg of all the ſtands, fixed as well as moveable, a plate of braſs is ſcrewed near the bottom, with two holes in each, over a groove purpoſely made in the wood underneath. By means of theſe plates, parallelopid leaden weights, about fourteen pounds each, having braſs pins with heads ſuited to enter the holes, and fall down in the grooves, into a narrow-pointed part of them, are readily ſlipped on or off each leg. Thus every ſtand, excluſive of its own weight, which is about thirty-one pounds, being loaded with forty-two pounds of lead, is thereby rendered perfectly firm and ſteady.

A number of wedges were alſo prepared, and always ready to be placed under the legs; by means of which, and a ſpirit level laid on the table, its plane is brought to the proper poſition.

Notwithſtanding all theſe precautions, it having been found, in the meaſurement with the deal rods, that time was loſt in levelling the ſtands, particularly in ſituations where the ſurface happened to be more than uſually uneven, or where it was of a looſe or ſpungy nature; therefore Mr. SMEATON adviſed (and no man's advice is more deſerving of attention), that deal platforms, ſtanding on pickets driven into the ground, and properly levelled, ſhould be uſed to receive the legs of the ſtands. Accordingly, for the operation with the glaſs rods (table XIX.) twenty ſuch triangular platforms made of inch deal, whoſe ſides were each three feet two inches in length, and void in the middle, were provided; as alſo a number of beech-pickets, about an inch and a half ſquare, and of different lengths, from ſeven to twelve or fourteen inches. Three of theſe pickets, ſhort or long as the ſituation required, being driven into the ground, till their heads (by the carpenter's level)

level) were brought to the proper height, the platform was laid upon them; and on that the ſtand itſelf being placed, its poſition was ultimately corrected by the ſpirit level laid on the top of the table. Each of the beech pickets had a hole bored through its top, fit to receive a piece of ſtrong tent-line, by which, and the help of one of the camp mallets, the pickets were eaſily pulled up again, when the platform was to be removed to a new ſituation.

Boning Teleſcope and Rods. Tab. XVIII.

In order to trace the line of 200 yards or 600 feet through the air, from one fixed ſtand to the other, it was uſual, in the firſt place, to ſtretch a cord extremely tight along the ground, and to divide the ſpace into rod lengths, by ſmall wooden pins placed cloſe by the cord, which remained there, and accordingly marked, very nearly, the points over which the centers of the intermediate ſtands were to come. A piece of wood, about fourteen inches in length, and one and a half in breadth, painted white, with a narrow black line along the middle of it, being prepared for the purpoſe, was laid on the ſurface of the farther ſtand. The boning teleſcope, fourteen inches long and one and a half in diameter, with a ſmall magnifying power, and moveable object-glaſs, ſo as to fit it for very ſhort diſtances, was then laid on the ſurface of the neareſt ſtand; which, by means of wedges placed under the legs, had that ſide towards the farther ſtand ſo elevated or depreſſed, as to bring the croſs wires to coincide with the black line on the painted board. Twenty-four boning rods had been originally provided; but it rarely happened, that more than eight or ten of that number were uſed in any one ſtation. They are of clean deal, upwards of five feet in length, one inch ſquare, and pointed with plate iron at the bottom, ſo as to be eaſily fixed into the ground. Each rod carries a croſs vane, ſix or ſeven inches in length, and three-quarters of an inch in breadth. This croſs vane, being moved upwards or downwards along the rod, till its upper ſurface coincided with the croſs wires of the teleſcope and black line on the painted board, its under ſurface then marked the height to which the ſurface of the ſtand was to be brought at that particular place. In this manner, a certain number of points, in the line paſſing through the air from one fixed ſtand to the other, being accurately obtained, it was very eaſy, at all the intermediate places, by the application of the eye alone to the ſurface of any one ſtand or rod, to bring the ſurfaces of the other ſtands near it into the ſame plane.

Cup and Tripod for preſerving the point upon the ground, where the meaſurement was diſcontinued at night, and reſumed next morning. Tab. XVIII.

It has been already mentioned, and, in giving the account of the rough meaſurement with the chain, there will be farther occaſion to remark, that the baſe was divided into hypothenuſes of 200 yards or 600 feet each, where ſquare pickets were driven into the ground, and regularly numbered, ſo as to be eaſily referred to on any occaſion. In the meaſurement with the rods, it was cuſtomary to finiſh the day's work at or near one of theſe ſtations. When the rods of twenty feet were uſed, the termination of a rod was, of courſe, always found to be within a few inches of the picket correſponding with the hypothenuſe, as determined by the chain. But with the rods of twenty feet three inches, the day's work was always ended with a fractional rod, by ſuſpending a plummet from ſome convenient part of the ſtem, marked for the purpoſe, and which conſequently became the point of commencement next morning.

The braſs cup, made uſe of on theſe occaſions, is of the figure of an inverted truncated cone, whoſe mean diameter is four inches, and its depth about five, with a very ſmall inclination in the ſides. It was placed in a hole dug for it in the earth, immediately under the point of ſuſpenſion of the plummet, ſerving only to hold the water in which it vibrated.

The nature of the tripod will be beſt conceived from the plan and elevation of it in tab. XVIII. It conſiſts of two ſtrong pieces of beech wood, mortoiſed into each other, ſo as to reſemble a half croſs, or the letter T inverted, having three ſtrong iron prongs, about twelve inches in length, which paſs through the ends of the wood, and are faſtened to it by ſquare nuts at top. On the ſurface of the tripod lies a ſimilar half croſs of mahogany, moveable by means of grooves in the direction of the longeſt ſide, and fixable by its proper ſcrews, when brought to the deſired poſition. This mahogany half-croſs carries on its ſurface a braſs ruler, moveable at right-angles to the former direction, fixable alſo by means of its own ſcrews, and on whoſe end is cut a very fine interſection. Thus any day's operation having been finiſhed, the tripod was placed near the cup, with it longeſt ſide parallel to the line of meaſurement, and its prongs driven into the ground, ſo as to be rendered perfectly immoveable without great violence. The plummet being then ſuſpended by a fine gilt wire, at any part of the ſtem of the deal rods indifferently, but always at the fixed * or hindermoſt end of the glaſs rods, the braſs ruler was advanced ſo near as almoſt to touch the wire, and there made faſt. This being done, the mahogany half-croſs was laſtly moved backwards or forwards, in the direction of the line of meaſurement, until the interſection, as ſeen by a perſon lying down on the ground for the purpoſe, accurately coincided with the gilt wire, where it was likewiſe faſtened by its proper ſcrews. A tent was then pitched very near the apparatus, for the ſoldiers who furniſhed the centinel for its ſecurity, till the meaſurement was reſumed; and particularly to guard it from being diſturbed by cattle during the night.

Wheels for terminating, in a permanent manner, the extremities of the Baſe. Tab. XVIII.

Before any accurate meaſurement could ultimately be made of the baſe by means of rods, in order that we might with certainty refer to the ſame point, on any occaſion that might ariſe of correction or repetition of the work, it had all along been foreſeen, that it would be abſolutely neceſſary to ſink deep into the ground wooden pipes, or ſuch like things, at the extremities of the baſe, which could not be removed, or even diſturbed, by idle or ignorant people, without very conſiderable labour. Mr. MYLNE, F.R.S. was accordingly requeſted to order two ſuch pipes to be provided, about ſix feet in length each, and one foot in diameter, with a bore of four inches in the uppermoſt end, for the depth of two feet, and croſs-arms near the lowermoſt end, in the ſtile of the common warping poſts. As an improvement on this idea, Mr. MYLNE very judiciouſly propoſed that, inſtead of the croſs-arms, the lower ends of the pipes ſhould paſs through the nave of an old coach-wheel, and then be ſecured by a bolt underneath. This alteration was approved of; and the machines, thus executed, were ſent ſoon after by water to Hampton.

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* That this might be conveniently done, a moveable ſtand was placed, under the glaſs rod, about four feet from the fixed end, and its table elevated till, by bearing againſt the lower part of the caſe, it received its weight. This permitted the ſtand under the fixed end to be lowered and removed, to make room for the apparatus.

The plan and ſection of one of theſe wheels, with the diſhed ſide downwards, are repreſented towards the left-hand in tab. XVIII. where it will be perceived, that by means of four knee-pieces, made of crooked oak, the pipe is firmly bolted to the wheel, and thereby kept at right-angles to its plane. The top of the pipe is alſo ſecured exteriorly by an iron hoop, and has a caſt-iron box driven into it, whoſe inner diameter is four inches, anſwering to that of the bore. Four oak piles for each wheel were prepared to be driven into the bottoms of the pits dug for their reception, which were ſix feet in diameter, and the ſame in depth. The ſoil near Hampton Poor-houſe being of a looſe ſandy nature, there the piles were eaſily driven into the bottom, until their tops were on the ſame level. The flat of the fellies of the wheel being then laid on the piles, the earth was filled in and well rammed around the pipe, quite up to the ſurface, with which its mouth is even. But the ſoil at King's Arbour, being a hard-bound gravel, the piles could not be driven into the bottom of that pit; wherefore, the flat of the wheel reſts there on the gravel only.

The braſs cup, formerly deſcribed, was from the firſt intended to be placed in the pipes, for which purpoſe it has two lids; one a ſemi-circle, with the central point marked by a *line* cut on its diameter, brought into the direction of the baſe; with which line the gilt wire, ſuſpended at the extremity of the firſt rod, was made to coincide on the commencement of the meaſurement. The other lid has a very ſmall hole made in its center, through which the plummet wire is to paſs, when ſuſpended from the center of the inſtrument, hereafter to be made uſe of for the determination of the angles at the baſe, or in any other ſtation whatever, where it may be neceſſary to bring it very accurately over a point on the ſurface of the ground underneath.

Rough meaſurement of the Baſe with the Chain, and determination of the relative heights of the Stations by means of the Teleſcopic Spirit Level. Tab. XVI. and XVII.

Having in the preceding deſcription of the various inſtruments, originally provided for the meaſurement of the baſe, fully explained their conſtructions, uſes, and modes of application; and having thereby anticipated, in a great degree, what muſt otherwiſe have been ſaid to make them underſtood in any account, blended with that of the execution; little more now remains to be given than the journal of our proceedings from day to day, and the ultimate reſult of the operation.

After a very tedious delay, Mr. RAMSDEN having at laſt produced his hundred-feet chain, with the portable tranſit inſtrument; and having lent us an excellent teleſcopic ſpirit level, for determining the relative heights; two ſections of the baſe being likewiſe cleared by the ſoldiers, and ſome progreſs made in

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the third, we found ourſelves, on the 16th of June, in readineſs to begin the rough meaſurement.

Lieut. Colonel CALDERWOOD, of his Majeſty's Horſe-Guards, F.R.S. had, from the beginning, been ſo good as to promiſe his aſſiſtance in the operation. Lieut. Colonel PRINGLE too, of the Corps of Engineers, obligingly became a volunteer on the occaſion; as did alſo Mr. LLOYD, F.R.S. a few days afterwards; while Enſign REYNOLDS, of the 34th regiment, who had for ſome time paſt been employed in ſurveying the environs of the Heath, continued that work with ſuch ſpare hands as could be afforded him for that purpoſe; and it is to the plan (tab. XVI.) done by that officer, that it will be neceſſary to refer in any thing regarding locality, in what has hitherto been ſaid, as well as in the ſubſequent relation.

The lower end of the baſe had for ſome time paſt been diſtinguiſhed by a St. George's flag fixed to the top of a fir ſpar, thirty-five feet in height; and one of the ſignal bell-tents ſtill remained at the ſtation near the ſummer-houſe. A rope of 200 yards being made very faſt by a ſtrong iron picket, driven into the ground at the bottom of the flag-ſtaff, the other end was carried on along the baſe, and placed at the bottom of a camp-colour, in a line with the bell-tent. The rope being wound around a ſtrong iron reel, prepared for the purpoſe, was thereby ſtretched extremely tight, a perſon occaſionally lifting it up in the middle, or at other places, and letting it drop again, ſo as to bring the whole into the ſame ſtraight line. Five perſons were neceſſary for the proper management of the chain; two at each end for its adjuſtment there, and one towards the middle, to lay it cloſe to the rope, or to bear it up in any particular place, where the circumſtances of the ground rendered ſuch precautions uſeful. The zero or rear end of the chain being ſtrained back ſo as to coincide with the point of commencement, a ſteel arrow was placed as erect as poſſible in the ſemi-circular cavity of the braſs handle at the other end. The chain being then drawn on, till the cavity in the rear handle could be applied to the firſt arrow, a ſecond was then placed in that of the front handle, and ſo on until ſix chain lengths were thus meaſured off; which terminating the firſt hypothenuſe, a beech picket, ſomething more than an inch ſquare, and about ſeven in length, with N° 1. cut upon it, was driven into the ground, till its head was nearly level with the ſurface. It is however to be remarked, that the ſixth arrow of each hypothenuſe was conſtantly left in the ground till the firſt of the ſucceeding one was placed, to avoid the error that would have otherwiſe ariſen in applying the rear end of the chain to the picket inſtead of the arrow.

In this manner we proceeded on the 16th of June, and in the ſpace of about three hours and a half, completed the firſt meaſurement of the ſouth-eaſt ſection of the baſe, comprehending the thirteen hypothenuſes between the flag-ſtaff and ſtation near Hanworth Summer-houſe, the diſtance being 78 chains or 7800 feet, making 2600 yards; and the mean temperature of the air being 63°.

On the ſubſequent day this ſection was re-meaſured with equal care, when the total extent fell ſhort of the thirteenth picket only five inches. And here it is to be obſerved, that a conſiderable part of this difference probably aroſe from the ſtretching of the chain acroſs Wolſey River, at the ſame time that the irregularities of the ground are greater in this than in either of the other two ſections. The mean heat of this day was 65°.

The operation with the chain was ſuſpended during the 18th and 19th of June, thoſe days having been employed in ſettling certain matters with Mr. RAMSDEN relative to the deal rods, as well as to give time for the making of a holdfaſt for the rear end of the chain, invented by Lieut. Colonel PRINGLE. This machine, whereof the plan at large is repreſented by dotted lines at the handle of the chain, as it is in ſmall by the two elevations adjoining in tab. XVII. conſiſts of a ſemi-circular iron plate, from the bottom of which projects two double and one ſingle prong. In the middle, between the two double prongs, a ſemi-circular cavity is formed, fitted to receive the ſteel arrow on one ſide, while that in the braſs receives it on the other. In a ſocket in the middle, a ſtrong wooden handle, reſembling that of a ſpade, is placed. Thus the rear handle of the chain being applied to the arrow, the holdfaſt embraces with its double prongs the ſtraight part of the braſs, and in that poſition, being forced into the ground by the action of a man at the handle, the rear end of the chain is thereby kept ſo firm as to be immoveable by the efforts of the two men at the other end, in ſtretching it to its true poſition, for the front arrow.

On Monday, the 21ſt of June, the operations were reſumed, by meaſuring twice with the chain (forwards and again backwards) the thirteen hypothenuſes comprehended in the ſecond ſection of the baſe, between Hanworth Summer-houſe and the north-weſt bank of the great road (an old Roman way) leading from Staines to London. This being the ſmootheſt part of the Heath, and the holdfaſt being now applied, the two meaſurements differed only one inch and a half in the diſtance of 7800 feet. This inſtance of accuracy is alone ſufficient to prove the great excellence of the chain, although another will be given hereafter ſtill more ſurpriſing.

On the ſame day that the ſecond ſection of the baſe was meaſured, the levels of that and the firſt were taken. The operation of levelling is ſo univerſally known, as to render any detail of it unneceſſary. It will be ſufficient to ſay, that the ſpirit level made uſe of on this occaſion was a very good one, about eighteen inches in length, and could at all times be very readily and accurately adjuſted by inverſion in its Y's. The tops of the pickets, marking the hypothenuſal diſtances, were the points on which the levelling rods were placed on each ſide of the level; which being inverted at the intermediate picket, points equi-diſtant from the center of the earth were thereby obtained, at the croſs vanes of the levelling rods, and no correction for curvature or refraction neceſſary. It will be readily underſtood, that the relative heights of the pickets were found by meaſuring their diſtances from the centers of the croſs vanes and axis of the teleſcope reſpectively.

The ſix firſt columns towards the left-hand of the firſt or general table ſubjoined to this Paper, ſhew diſtinctly every thing relating to the levels of the whole baſe, thoſe of the third ſection having been determined on the 22d of June. By examining the table it will be ſeen, that the aſcent on the firſt ſection is 10.555 feet,
on the ſecond . 8.580
and on the third . 12.130
Total . . 31.265 feet, between the lower extremity at Hampton Poor-houſe, and the higher near King's-Arbour.

The computed numbers in the ſeventh column are the reductions * depending on the aforeſaid heights, or the differences between the hypothenuſal diſtances of 600 feet each and the reduced baſe diſtances. With regard to the remaining columns of the table, or thoſe towards the right-hand, they will be ſeverally ſpoken to hereafter, in taking into conſideration the expanſion of metals, as determined with great accuracy by the experiments with the pyrometer.

Hitherto no uſe had been made of the tranſit inſtrument: for, in order that it might be applied to advantage, there was a neceſſity for laying the wheel into the ground at the lower end of the baſe, and ſo to modify the St. George's flag-ſtaff that, being placed in the pipe, it might be ſteadily ſupported by braces in a true vertical poſition; which we found, from experience, could not be effected by ropes only.

The wheel being accordingly laid in its place, and the other precautions taken for ſecuring the flag-ſtaff, which was likewiſe painted white, that it might be more diſtinctly ſeen from

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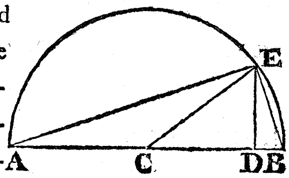

* The reduction in the ſeventh column, I have computed by the difference between the ſquare of the hypothenuſe, actually meaſured, and the ſquare of the height found by the level; and Lieut. Colonel CALDERWOOD has done the ſame thing by a much ſhorter method. Thus, in the annexed figure, CE being the hypothenuſe of 600 feet, DE the perpendicular height obtained by levelling, DB the reduction required, or the difference between the hypothenuſe and true baſe; then, ſubſtituting the chord BE inſtead of DE, the following analogy is obtained; AB : BE :: BE : DB; conſequently, $\frac{BE^2}{AB} = DB$: that is, the ſquare of the perpendicular height being divided by double the diſtance, or 1200 feet, the quotient is equal to DB the reduction, without ſenſible error. For if DE were four feet, the greateſt perpendicular height in the baſe, BE the chord would only exceed it $\frac{1}{200000}$, which would not be more than $\frac{1}{4000}$ part of an inch. The difference between the reſults, by the two modes of computation, is ſo trifling as not to deſerve notice.

the farther extremity; on the 22d of June, the tranſit inſtrument was adjuſted over the thirteenth picket at Hanworth Summer-houſe, while directed upon the flag-ſtaff. But it being now found, that the vertical plane paſſing through the flag-ſtaff fell to the eaſtward of the center of Banſted Spire, therefore the tranſit was gradually moved to the eaſtward, until by repeated trials the three points were perceived to be in the ſame vertical plane, when the picket was moved, and re-placed exactly under the axis of the teleſcope, a few inches from its firſt poſition. The ſame operation was repeated at the twenty-ſixth ſtation, on the farther bank of the Staines Road; and, laſtly, at the forty-ſixth, forming the north-weſt extremity of the baſe; where a pit was immediately dug for the wheel, which was placed therein, without however filling in the earth for the preſent, that being deferred till near the completion of the meaſurement with the deal rods. Thus the two extremities, and two intermediate points of the baſe, being accurately placed, by the help of the tranſit inſtrument, in the ſame vertical plane with Banſted Spire, it was eaſily ſeen, that by arranging camp colours in the intervals at any time, all the other points might be brought ſo nearly to coincide with theſe firſt, as not to occaſion, by deviation, any ſenſible error in the meaſurement afterwards to be made. This application of the tranſit ſhewed us, however, that ſome labour had been loſt by not uſing it ſooner: for at the Staines Road, the tract cleared by the ſoldiers deviated about two feet and a half too much to the weſtward for the true line; and at King's Arbour it was twice as much; ſo that we were now obliged to widen the cleared tract, by adding to the eaſtern ſide of it.

On the ſame day that the chief points in the baſe were fixed by means of the tranſit, and the levels of the third ſection taken as before-mentioned, the rough meaſurement of that ſection with the chain was completed, and found to contain nineteen hypothenuſal diſtances of 600 feet each, and one of 404.55, making in the whole 11804.55 feet, between the twenty-ſixth ſtation at the Staines Road and the center of the pipe near King's Arbour, the mean temperature being 62°½. Here it is to be obſerved, that this laſt ſection was only meaſured once with the chain, the tract not being yet ſufficiently cleared to admit of its being done to the beſt advantage; and, when completed, it was judged to be better to proceed directly in the operation with the rods, than to loſe time in the uſual repetition, ſince the merits of the chain, in this way of applying it, were already ſufficiently well eſtabliſhed; and any future teſts to which it was to be put were propoſed to be of a more rigid nature.

When the length of the chain, in its original ſtate, was aſcertained by the dots on the braſs pins in the New-England plank, it was found, in the then temperature of 74°, to exceed the 100 feet by near one quarter of an inch, or 0.245 inch. Therefore, in the temperature of 63°, being that in which the lengths of the deal rods were laid off, and differing very little from what was likewiſe the mean heat of the air, when applied upon the Heath, the chain, according to the experiments on the expanſion of the very ſame ſteel, would exceed the 100 feet by 0.161 inch, or 0.0134 foot. Hence the ſum of the three ſections of the baſe, 274 chains, being multiplied by 0.0134 foot, we ſhall have 3.67 feet for the equation of the chain + 4.55 feet, to be added to its length, which will then become 27408.22 feet from the center of one pipe to the center of the other: and this would have been the true length of the baſe, as given by the rough meaſurement with the chain, if the ſurface had been one uniform inclined plane throughout its whole extent. But, although the aſcent of Hounſlow-Heath is ſo ſmall, and ſo gradual, as to occaſion little more than half an inch of reduction, from the 46 hypothenuſal to the 46 baſe diſtances, into which it is divided, as may be ſeen by referring to the table; yet each of theſe hypothenuſes containing again many other ſmall irregularities, all of which affect the meaſurement by the chain, in proportion to their number and height, in every ſpace of 600 feet, their united effects, including the lateral deviations from the true line in meaſuring, do ſomewhat more than compenſate for the extra-length of the chain, as will be ſeen hereafter in comparing the length of the baſe juſt now obtained with that given by the rods.

The weather, which during the greater part of June had been wet, became ſtill worſe towards the end of the month and firſt week of July; ſo much ſo, that even if the deal rods had been ready they could not have been uſed with advantage. The ſoldiers, nevertheleſs, were not idle, being, when the weather would permit, partly employed in clearing the Heath, and partly in aſſiſting Mr. REYNOLDS in the ſurvey, towards the perfecting of which many chief points were fixed by means of my aſtronomical quadrant, placed for that purpoſe at ſeveral different ſtations of the baſe. At this time too (July 8th) I levelled from the lower end of the baſe to the ſurface of the Thames at Hampton, and found the deſcent to be 36.1 feet.

Meaſurement of the Baſe with the Deal Rods.
Tab. XVI. and XVIII.

Such extraordinary care and pains had been beſtowed in the conſtruction of the deal rods, in order to render them the beſt which had ever been made, that, although begun early in June, they were not completely finiſhed before the 15th of July. They were brought that afternoon by Mr. RAMSDEN, together with the various parts of the apparatus neceſſary for their application in the field, to the camp now moved from Hanworth Summer-houſe to the interſection of the baſe with Wolſey River; whence they were tranſported, early next morning, to the pipe near Hampton Poor-houſe, where we were met by Sir JOSEPH BANKS, accompanied by Meſſ. BLAGDEN, CAVENDISH, LLOYD, and SMEATON, all ready to lend their aſſiſtance in the ſubſequent menſuration.

Before I proceed farther, I think it here incumbent upon me very gratefully to remark, that the reſpectable and very worthy Preſident of the Royal Society, ever zealous in the cauſe of ſcience, and who had repeatedly viſited the heath, to offer aid, if ſuch had been neceſſary, while the firſt and rougher part of the operations were going on; now, that others of a more delicate nature were to commence, and where it was of importance, that thoſe entruſted with the execution ſhould meet with as few, and as ſhort, interruptions as poſſible, not only gave his attendance from morning to night in the field, during the whole progreſs of the work; but alſo, with that liberality of mind which diſtinguiſhes all his actions, ordered his tents to be continually pitched near at hand, where his immediate gueſts, and the numerous viſitors whom curioſity drew to the ſpot, met with the moſt hoſpitable ſupply of every neceſſary and even elegant refreſhment. It will eaſily be imagined, how greatly this tended to expedite the work, and how much more comfortable and pleaſant it rendered the labour to all who obligingly took part in it; but more eſpecially to him, who, being a volunteer in it at firſt, conſidered himſelf as bound to perſevere in his beſt endeavours to bring it to a ſucceſsful concluſion.

From the deſcription that has been given of the deal rods, it will be remembered, that they are fitted to be applied in meaſuring, either by the coincidences of lines, inlaid one inch and a half from each extremity, or by the contacts of the ſpherical lips of the bell-metal with which they are tipped. The firſt, ſeeming to be the moſt accurate, although the moſt tedious method, was that by which we propoſed to ſet out.

The flag-ſtaff having been previouſly removed from the pipe, and the braſs cup filled with water put in its ſtead, all the neceſſary precautions being likewiſe taken for preſerving the line of direction, horizontally, by the rope ſtretched along the firſt hypothenuſe, and vertically, by means of the boning rods; the firſt ivory line on the firſt rod was brought by the plummet to coincide with the center of the cup, in which poſition, being clamped, it accurately marked the commencement of the baſe. The ſecond rod being now applied to the firſt, and moved up by the apparatus formerly deſcribed (tab. XVIII.) till its line coincided with that on the firſt; and, in like manner, the third rod being applied on the alternate ſide of the ſecond, moved up and clamped as the reſt; thus the exact diſtance of ſixty feet was aſcertained, care being always taken, that the firſt adjuſtments were not diſturbed, while the ſubſequent ones were forming. The clamps faſtening the firſt rod to its ſtands being then detached, it was carried by two men and laid on the alternate ſide of the third; and ſo on in ſucceſſion, until fifteen rod lengths were meaſured off, being the half of the firſt hypothenuſe.

The time conſumed in meaſuring this ſhort diſtance of 300 feet was not leſs than five hours; owing, as has been formerly mentioned, to the confined nature of the apparatus for moving the rods on into coincidence, which required ſuch nicety in placing the ſtands, as could not be effected until after ſeveral repeated unſucceſsful trials. All the executive people were therefore of opinion, that it would be proper to diſcontinue this mode of meaſurement, at leaſt until a more convenient apparatus could be thought of for the purpoſe; and that, in the mean time, we ſhould proceed by the method of contacts, as the only alternative we could for the preſent adopt*.

The rods being accordingly placed in contact with each other, we ſoon made greater progreſs, finiſhing the operations of the day at the middle of the fourth hypothenuſe, where the tripod, with its guard, was placed, to preſerve the point of commencement for the enſuing morning.

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* Although I acquieſced in the change thus become neceſſary, yet it was with much reluctance, becauſe it left undecided the conteſted point, with regard to coincidences and contacts. If we could have proceeded with the coincident rods till eighty-one lengths were meaſured off, and then meaſured back the ſame ſpace by placing eighty rods in contact, the point would have been clearly ſettled. For if the termination of the eightieth rod agreed exactly with the point of departure, contacts being the moſt expeditious would have been judged the beſt method. On the contrary, if the eightieth rod fell ſhort of reaching the point of departure, there could have been no doubt, that the difference muſt have ariſen from butting one rod againſt the other, whereby a certain ſmall proportion of each rod came to be loſt in the account, by being meaſured twice over.

The meaſuring rods, when put into the cheſt in London, had been compared and found to agree with the ſtandard. The compariſon was not repeated on the 16th; but this being done on the 17th, at 7 h. A.M. under the oil-cloth canopy at the camp, they were found at a medium to exceed the ſtandard by one-fiftieth of an inch, the temperature then being 62°. After the compariſon they were carried to the place of the tripod, when the operation was reſumed by bringing, with the help of the plummet, the ſame point of the rod with which we had left off work, to coincide with the interſection on the braſs ruler. The meaſurement of this day was cloſed at the end of the tenth hypothenuſe, when the rods being carried back to camp, were compared, and found accurately to agree with the ſtandard.

A conſiderable fall in the barometer, between the evening of the 17th and the morning of the 19th, portended rain. Neverthele ſs, all parties repaired to the place of rendezvous, which was appointed at the lower end of the baſe, in order to re-meaſure the two firſt hypothenuſes, by placing all the rods in contact, which on the 16th had been done partly one way and partly the other. The operation being according repeated with great care, the point of the ſixtieth rod, which formerly correſponded to the center of the ſecond picket, was now found to be puſhed forward exactly forty-five inches, anſwerable to the deficiency on the fifteen coincident rods, with which the menſuration was begun. It now began to rain, therefore the rods were carried back to camp, and being ſeverally compared, they were found to exceed the ſtandard each by one-thirtieth of an inch, occaſioned by the extraordinary humidity of the air. A heavy rain enſued; and what made this much more regretted by all was, that in the forenoon their Majeſties graciouſly condeſcended to honour the camp with their preſence, and continued there ſome time; but the weather becoming rather worſe, it was utterly impoſſible to ſhew their Majeſties the nature of the operation, by any progreſs that could at that time be made in the work.

After a continuance of unfavourable weather for ſeveral days, the operations were reſumed at 9 h. A.M. of the 23d, when the rods being compared were found ſtill to exceed the ſtandard by one-thirtieth of an inch, and the temperature now was 61°. Here it is to be obſerved, that in our progreſs forward, an accurate regiſter had been all along kept of that point of each rod correſponding to the center of the hypothenuſal pickets, by noting its diſtance from either end, whereby the error of the chain at each ſtation was readily diſcovered, at the ſame time that the revolutions of the three rods ſerved to keep the account of the total meaſurement. In order, therefore, that this method might be diſtinctly adhered to, it was judged proper to puſh on the rod that lay over the tripod at N° 10. exactly forty-five inches, to make good the deficiency of the firſt fifteen coincident rods, and that the account might be kept from the lower end of the baſe in entire rods of 243, and complete revolutions of 729 inches each. This being done, the reſt were placed in the ordinary ſucceſſion; and we finiſhed the buſineſs of the day at the eighteenth ſtation, where the rods being compared at 6 h. P.M. their mean length was found to exceed that of the ſtandard $\frac{1}{67}$th part of an inch, the temperature then being 54°.

On Saturday the 24th of July, the rods were three times compared; at 7 h. 30′ A.M., 11 h. 15′ A.M., and 5 h. 45′ P.M. Their mean exceſs above the ſtandard was found to be one-thirtieth of an inch, and the mean heat 64°. In the courſe of the day, the meaſurement was continued from the eighteenth to the twenty-ſeventh ſtation, or firſt of the third ſection of the baſe, where the tripod was placed as uſual; and there it remained untouched, on account of bad weather, till Monday the 2d of Auguſt.

Conſidering how much time and labour had been beſtowed in obtaining what we certainly had every reaſon to conclude were the beſt deal rods that ever were made, it was no ſmall diſappointment now to find, that they were ſo liable to lengthen and ſhorten by the humid and dry ſtates of the atmoſphere, as to leave us no hopes of being able, by their means, to determine the length of the baſe to that degree of preciſion we had all along aimed at. But ſince more than one-half of it was already meaſured, it was judged proper to proceed with them in their preſent ſtate, and then to have them carefully painted or varniſhed, before they ſhould be farther uſed.

The unfavourableneſs of the ſeaſon, and delays in obtaining the inſtruments, had already been the cauſes of protracting the operations on Hounſlow-Heath greatly beyond what was at firſt expected; and the failure of the deal rods gave no immediate proſpect of their being ſpeedily brought to a concluſion. On revolving in my own mind the different alternatives we might ultimately be obliged to have recourſe to, metal rods of ſome kind or other, whoſe expanſion could always be determined by experiment, ſeemed to promiſe a reſult that might be ſafely relied on. Caſt iron was what I had thoughts of propoſing, knowing from an experiment which I had made myſelf, that it expanded leſs than ſteel. The cumberſomeneſs of its weight appeared indeed objectionable; but that inconvenience was either to be ſubmitted to, or one of another kind, namely, the reduction of the length, which was always, if poſſible, to be avoided.

At this time Lieut. Colonel CALDERWOOD could not conveniently lend us his aſſiſtance in the field; but he viſited us occaſionally, and on one of theſe viſits propoſed to me, that glaſs rods ſhould be made uſe of inſtead of deal; putting me in mind of another experiment * that I had made, which ſeemed to ſhew that ſolid glaſs rods expanded leſs than tubes. This propoſition the Lieutenant-Colonel, before he came to the heath, had made to Mr. RAMSDEN, who appeared averſe from making the trial, becauſe of the great length of the rods, and the brittleneſs of the material. Nevertheleſs, it being ſufficiently obvious, that glaſs rods or tubes of the full length, or ſomething approaching towards it, would be much ſooner provided than any metal rods whatever, and the ſaving of time being a point of conſequence; Lieut. Colonel CALDERWOOD was accordingly requeſted to make the trial at the glaſs-houſe, as ſoon as poſſible after his return to town. Next day he ſucceeded in getting a fine tube drawn, eighteen feet long, and about one inch in diameter; and there ſeemed to be no longer any doubt, that thoſe of the proper length might be obtained. It was found, that ſolid glaſs rods of ſuch extraordinary dimenſions could not be had, it being impoſſible to take at once a ſufficient

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* The experiment here alluded to was made with Mr. CUMMING's pyrometer, which from its conſtruction did not admit of a very accurate eſtimation of the heat communicated to the ſtandard bar, the rod, and tube reſpectively. Either, therefore, the natures of the glaſs rod and tube, made uſe of at that time, muſt have been very different, to cauſe the difference of expanſion; or ſome circumſtance in the inſtrument unattended to had occaſioned the fallacious appearance: for it will be found, from the experiments hereafter to be given in detail, that a ſolid glaſs pendulum rod expands fully as much as, nay in this particular inſtance even more than a tube; but different glaſs, having different ſpecific gravities, will no doubt be ſuſceptible of different degrees of expanſibility.

quantity of the melted metal on the irons, made uſe of for drawing them at the glaſs-houſe.

The week of rainy weather, which ended the month of July, occaſioning, as has been ſaid, a total ſuſpenſion of the operations on the heath, was employed in procuring a ſufficient number of glaſs tubes (one whereof was not leſs than twenty-ſix feet long) and regulating with Mr. Ramsden every thing concerning their conſtruction into meaſuring rods. The deſcription of them we ſhall however defer until the time of their application in the field, after having finiſhed the operation with thoſe of deal.

On Monday the 2d of Auguſt, the operations on the heath were reſumed at 8 h. 30′ A.M. by comparing the rods with the ſtandard, which they were found to exceed by one-fortieth of an inch, the temperature then being 66°. The forward end of the rod now placed over the tripod at N° 27, completing the 800th length, reckoned from the lower end of the baſe by rods of 243 inches each; and theſe being equal to 810 rods of 240 inches; it was judged proper to mark a point upon the ground correſponding to this forward end, that it might be referred to in returning back with the meaſurement by the glaſs rods. This was done by ſinking two ſmall pickets into the ground, about a foot aſunder, one on each ſide of the baſe, and at right angles to it. A ſilk thread being then ſtretched over the tops of the pickets, and gently moved on till it touched the ſilver wire ſuſpended from the end of the rod, fine notches were then made with a pen-knife in the tops of the pickets, whereby the thread could be replaced in the ſame ſituation; which being done, the pickets were covered over with earth. In the courſe of this day nine hypothenuſes were meaſured; and at 7 h. P.M. the tripod was placed at the thirty-ſixth ſtation. The rods, being now compared, were found to agree with the ſtandard; and the temperature was 67°½.

On Tueſday the 3d of Auguſt, the rods were compared at 7 h. A.M. and found only to exceed the ſtandard by one-ſixtieth of an inch. Being arrived at the middle of the forty-firſt hypothenuſe, a point correſponding to the forward end of the 1215th rod was transferred to the ground by the double pickets and ſilk-thread, as had been done at the twenty-ſeventh ſtation. The meaſurement was then continued to the north-weſt extremity of the baſe, which was found in the whole to contain 1353 complete long rods of 243 inches each + 21 inches, where the tripod was placed, in the point which of courſe correſponded to the 1370th ſhort rod of 240 inches each, equal to 328800 inches, or 27400 feet. To which diſtance we have yet to add 4.31 feet, being the ſpace intercepted between the interſection on the tripod and the center of the pipe marking the north-weſt extremity of the baſe; whoſe total length, as given by the deal rods, without regard to expanſion, or reduction of the hypothenuſal line, becomes 27404.31 feet. And here it is to be obſerved, that the interſection on the tripod terminating the 27400 feet only over-ſhot the picket anſwering to the 274th chain by two inches and nine-tenths. But this nice agreement between the reſult by the deal rods, and that furniſhed by the rough meaſurement with the chain, ariſes from the extra-length of this laſt, which ſo nearly compenſated for all the irregularities of the ſurface.

The meaſurement with the deal rods being finiſhed, they were compared at 5 h. PM. and found to agree with the ſtandard, the temperature then being 75°.

Expanſion of the Deal Rods.

It has been an opinion generally enough, although, as we have ſeen, erroneouſly received, that very ſtraight-fibred deal was not at all, or but little, affected longitudinally by the humidity of the air. That we might not be led aſtray by truſting to fallacies of this ſort, the ſtandard rod had been provided; which being always cloſely ſhut up in its cheſt, except during the ſhort interim of compariſon, could feel but a ſmall proportion of the effects which the meaſuring rods ſuffered, theſe being conſtantly expoſed to the open air throughout the day, as well as to the moiſture of the night, when lying under the oil-cloth canopy. The ſtandard rod, it is true, could not be accurately compared with the braſs ſcale: for although when conſtructed, braſs pins, forty inches aſunder, had been driven into its ſtem, for the purpoſe of ſuch compariſon, yet theſe had afterwards been diſplaced, or at leaſt the points upon them defaced, by the planing over of the upper ſurface. This circumſtance, which was unattended to when the operations commenced, is now of no conſequence; becauſe, from an experiment hereafter to be mentioned, the lengthening of the ſtandard may be pretty nearly aſcertained. But ſince there are ſome contradictory circumſtances, ſoon to be mentioned, in the operation with the deal rods, which would have made a repetition of it abſolutely neceſſary, if we had not now obtained thoſe of a different kind, ſo very unexceptionable in their nature and mode of application, as, in the preſent caſe, to admit of no competition between the two reſults, and to render it improper on our part ever to have farther recourſe to the firſt; ſo there can be little doubt, that deal rods will be univerſally rejected by other countries, in any meaſurements they may have occaſion to make in future.

About the 10th of July, two rods, one of New-England and the other of Riga deal, being meaſured by the fixed points in the great plank in Mr. RAMSDEN's ſhop, and having each two braſs pins driven into them at the diſtance of twenty feet, were laid on the top of the houſe, where they remained until the 26th, the weather, for the greater part of the time, having been very wet. They were then taken down, and being, by means of the long beam compaſſes, compared with the meaſures on the plank, the New-England rod was found to have lengthened 0.031 inch, and the Riga rod 0.041 inch. By which experiment the fact ſeems to be eſtabliſhed, that Riga red wood, notwithſtanding the quantity of turpentine which it contains, is more ſuſceptible of the effects of moiſture than New-England white wood. Mr. RAMSDEN likewiſe finds, that the great plank ſo often mentioned, ſuffers, in ordinary ſummer weather, an alternate expanſion and contraction, amounting at a medium to 0.0041 of an inch every day: that is to ſay, if the diſtance between the twenty-feet braſs points be meaſured from the ſcale, by means of the beam compaſſes, in the evening, it is found to have lengthened next morning 0.0041 of an inch, by the humidity of the intervening night. In the courſe of the following day it contracts again to its former length, and ſo on. Mr. RAMSDEN has often obſerved this alternate change in the deal plank; but it was particularly on the 11th and 12th of Auguſt, that the quantity was actually meaſured. It will readily be underſtood, that any difference of temperature which might have happened in the braſs ſcale, at the times of compariſon, was always carefully taken into the account.

Now, from this laſt experiment, it ſeems probable, that we ſhall not be very wide of the truth in ſuppoſing, that the ſtandard deal rod, which lay cloſed up in its cheſt, under the canopy on Hounſlow-Heath, would ſuffer the ſame ſort of alternate expanſion and contraction with the above-mentioned plank; that is to ſay, being of Riga wood, its mean expanſion about the middle of the day would be $\frac{25}{10000}$ of an inch. By this quantity then we muſt augment the actual obſerved expanſion of the meaſuring rods, in order to obtain within certain probable limits (ſince we cannot determine it accurately) the equation for the expanſion; or that ſpace by which the apparent meaſurement, given by the 1370 deal rods, ſhould be augmented in order to obtain the true length of the baſe; or that which would have been given by unalterable rods, of the ſame original length with thoſe of deal, as expreſſed in the following table.

Table of the Expanſion of the Deal Rods.

Days.	N° of rods meaſ.	Hour of compariſon.	Temp. of the air.	Obſerv-ed expanſion.	Deci-mal mean.	Equation for the meaſ. rods.	Equation for the ſtandard.	Total expan-ſion.
		h. ′	°	In.		In.	In.	In.
July 16	105	4 0A.M.	48	$\frac{1}{50}$th	0.010	1.050	0.2625	1.3125
		6 0P.M.	62	0				
17	195	7 0A.M.	62	$\frac{1}{50}$th	0.010	1.950	0.4875	2.4375
		6 0P.M.	—	0				
23	240	9 0A.M.	61	$\frac{1}{30}$	0.021	5.040	0.6000	5.6400
		6 0P.M.	54	$\frac{1}{67}$				
24	270	7 30A.M.	61	$\frac{1}{26}$	0.033	8.910	0.6650	9.5750
		11 15A.M.	66	$\frac{1}{31}$				
		5 45P.M.	64	$\frac{1}{33}$				
Aug. 2	270	8 30A.M.	66	$\frac{1}{30}$	0.0125	3.375	0.6650	4.0400
		7 0P.M.	67½	0				
3	290	7 0A.M.	56	$\frac{1}{60}$	0.017	0.493	0.7250	1.2180
		5 0P.M.	75	0				
Total	1370	– –	– –	– –	– –	20.818	3.405	24.223

N. B. Although the rods were not compared with the ſtandard on the 16th of July, yet the expanſion probably was, and therefore has been eſtimated, at the ſame rate as it was found on the following day.

By examining the preceding table, it will appear, that the total expanſion on the 1370 deal rods, including the ſmall equation for the lengthening of the ſtandard, amounts to 24.223 inches, or 2.02 feet; which being added to the apparent length of the baſe 27404.31 feet formerly obtained, we ſhall have, for the hypothenuſal length, 27406.33 feet: and from this deducting 0.07 foot, the exceſs of the hypothenuſal above the baſe line, or the reduction contained in the ſeventh column of the general table of the baſe, there will remain 27406.26 for the diſtance given, by the deal rods, between the centers of the pipes terminating the baſe, reduced to the level of the loweſt, or that at Hampton Poor-houſe, in the temperature of 63°, being that of the braſs ſcale when the lengths of the deal rods were laid off. All this, however, ſuppoſes three things to be abſolutely certain: firſt, that the expanſion of the rods has been accurately eſtimated; ſecondly, that no error has ariſen from the butting of the rods againſt each other, in order to bring them into contact; and, thirdly, that no miſtake of any kind has been committed in the execution. When we come to give the true length of the baſe, as ultimately aſcertained by means of the glaſs rods, it will appear, that one or more of theſe three have actually taken place; although it is moſt probable, that only the two firſt ſources of error have contributed their ſhare of the total difference between the two reſults. But the diſcuſſion of this point muſt be deferred for the preſent; and I ſhall now finiſh the ſubject of the expanſion of the deal rods, by mentioning two other compariſons of them, which ſerve to ſhew ſtill more obviouſly, how improper they are for very accurate meaſurement!

It has already been remarked, that the laſt week of July was ſo wet as to occaſion a total ſuſpenſion of the operations on Hounſlow-Heath. On the 26th of that month, at 8 h. A M. the temperature being then 63°, the rods were compared with the ſtandard, and found to exceed it, at a medium, one-fifteenth part of an inch. Now, if we ſuppoſe the whole baſe to have been meaſured with the rods in that ſtate, the difference would have amounted to more than 7½ feet, excluſive of what the ſtandard itſelf might have altered from its original length.

The other compariſon was made at Spring-Grove, in the beginning of September, after our operations on the heath had been finiſhed, and the deal rods with their apparatus depoſited under the roof of Sir JOSEPH BANKS's Barn. The object here in view was the meaſurement of ſuch a ſpace as the garden would conveniently admit of, when the rods were in their dry or contracted ſtate; and to re-meaſure the ſame ſpace next morning, when the rods, being left out for the purpoſe, had imbibed all the humidity they could from the moiſture of the intervening night. Accordingly, the fourth being a fine dry day, the ſun ſhining bright, and the thermometer about 68°, ſeventeen ſtands were arranged in the long walk, with ſo much nicety in the ſame inclined plane as to appear but like one. The firſt or lowermoſt ſtand had a braſs cock ſcrewed to its top. The two uppermoſt, that is to ſay, the ſixteenth and ſeventeenth, were of the fixed kind, each with a braſs ſlide, and placed only forty-five inches aſunder. The firſt deal rod was made to butt againſt the braſs cock, and the reſt ſucceſſively againſt each other, until fifteen rod lengths were meaſured off, and a fine line drawn on the ſlide marking the extremity of the fifteenth. That rod being removed, forty-five inches, taken from the braſs ſcale, were then laid off backwards from the line on the ſlide of the ſeventeenth to the ſlide of the ſixteenth ſtand, where another fine line was drawn. Thus the ſpace comprehended between this laſt line and the cock on the firſt ſtand, was juſt 300 feet, or fifteen coincident rods. During the night of the 4th, which was very fine, the rods lay on the ſmooth graſs. About ſun-riſing of the 5th there came on a thick fog, which entirely diſpelled about 8 o'clock. At 7 h. A.M. the rods being lifted from the graſs, it was perceived, that the under ſides were perfectly dry, while all the reſt was quite wet with the dew that had fallen. The fourteen ſtands, comprehended between the firſt and ſixteenth, having their diſtances gradually reduced from twenty feet three inches to twenty feet, the operation of re-meaſurement was then begun, by placing the rods in coincidence with each other (which was now found to be eaſily and accurately effected by a few repeated ſtrokes with a wooden wedge only) until the fifteen rod lengths were meaſured off, and a fine line, correſponding with the ivory on the fifteenth, was drawn on the braſs ſlide. This line was found to be $0.\frac{498}{1000}$, or near half an inch beyond that which terminated the 300 feet the preceding evening. Hence it is evident, that the dew imbibed only in one night, or a ſpace of time not exceeding fourteen hours, occaſioned ſuch an expanſion in the deal rods, as in the whole baſe would have amounted to 45.484 inches.

It is ſufficiently obvious, that this laſt mentioned experiment was more accurate, in the proportion of about fifteen to one, than any compariſon we could at that time have made with the ſtandard. But ſince immediately after it was finiſhed, the ſun ſhone out very bright, it is by no means certain, how ſoon the rods would again have contracted to their former length, or near it, had they been expoſed to his rays. Repeated compariſons for aſcertaining facts of this ſort, at very ſhort interims, are abſolutely incompatible with the nature of ſuch tedious and troubleſome operations as the meaſurement of long baſes: and here, indeed, lies the great objection to the uſe of deal rods, that at no time can we be certain how ſoon, after a compariſon has been made, they may alter their length in a proportion, and ſometimes too even in a ſenſe, different from what was expected.

Deſcription of the Glaſs Rods, ultimately made uſe of to determine the length of the Baſe. Tab. XIX.

It has been already mentioned, that the week of rainy weather in the end of July was employed in providing the glaſs tubes, and in concerting matters with Mr. RAMSDEN, relative to their conſtruction as meaſuring rods. Notwithſtanding their great length, they were found to be ſo ſtraight that, when laid on a table, the eye, placed at one end looking through them, could ſee any ſmall object in the axis of the bore at the other end.

The nature and conſtruction of the glaſs rods, whereof three were finiſhed for the operation, will be beſt conceived by conſidering, with care and attention, the plans and elevations of them, in whole or in part, to different ſcales in tab. XIX.; where likewiſe may be ſeen, plans and ſections of the ends of the tubes, in their real dimenſions, for the better underſtanding the ſeveral parts of the apparatus placed therein.

The caſe containing the tube, and which ſerves to keep it from bending in its original ſtraight poſition, is every where of the depth of eight inches, of the ſame width in the middle, and tapers from thence, in a curvilinear manner, towards each end, where it is only two inches and a quarter broad. It is made of clean white deal, the two ſides being half an inch, and the top and bottom three-eighths in thickneſs. Theſe laſt are placed in grooves fitted to receive them, about half an inch from the upper and lower edges of the ſides, which bending eaſily, and applying cloſely, are then firmly faſtened by two rows of wood ſcrews on each ſide, to the top and bottom reſpectively. Thus, the depth of the ſides in one ſenſe, and the ſpring which they have by bending in the other, act as truſſes, prevent the caſe from warping, and render it ſufficiently ſtrong, although at the ſame time, conſidering its great length, very light.

The plan of the middle rod repreſents the caſe with the top off, that the tube may be ſeen placed therein: the right and left-hand rods have the tops on, whereby may be ſeen the oval opening in the middle of each, ſhut by a mahogany lid; and alſo the poſitions of the two thermometers, with tubes bent at right-angles, ſo as to place the ball about two inches downwards within the caſe, for the better aſcertaining the temperature of the glaſs, as will eaſily be conceived, by conſidering the repreſentation of the tube and ball in the ſection acroſs the middle of the rod.

It is to be obſerved, that the middle of the tube is made faſt to the middle of the caſe in the following manner. Firſt, around the middle of the tube, a quantity of pack-thread, immerſed in liquid glue, was wound by ſeveral returns on itſelf, for the ſpace of about two inches in length; and upon this maſs of pack-thread, while the glue was warm, a ſtrong mahogany collar was forced; whereby the three ſubſtances became ſo perfectly united to each other, that they might be conſidered as one only. Acroſs the bottom of the caſe in the inſide, three mahogany braces or girders, one in the middle, and one half-way between it and each end, are faſtened, by means of ſcrews, to the bottom and ſides. Theſe riſe about 1½ inch above the bottom, ſo as to place the axis of the tube, when in uſe, about 2½ inches above the ſurface of the ſtands on which it reſts. The end-pieces of the caſe are likewiſe of mahogany, about 1¼ inch thick. Each conſiſts of two parts, a lower and an upper. In the lower parts, as well as in the croſs braces, there are ſemi-circular cavities lined with broad-cloth, fitted to receive the diameter of the tube, which reſts in them, and is conſequently ſupported at five different points. The upper end-pieces, having likewiſe ſemi-circular cavities fitted to embrace the upper part of the tube, ſlip down upon it, when it has been, by repeated trials, brought to its true poſition; that is to ſay, the axis of the bore into the ſame ſtraight line, the caſe being all the while ſupported by its extremities on two ſtands only, in the manner in which the rods are applied in actual meaſurement. The braces within the caſe have alſo their upper pieces, which, in like manner, apply cloſely to the tube, and are fixed to the lower ones by means of ſcrews. The whole together ſerve only as ſtays to keep the tube in its true place from ſhaking; but without binding it however too cloſely. Laſtly, the mahogany collar glued to the pack-thread on the middle of the tube, being ſtrongly fixed by four ſcrews to the middle brace, as may be ſeen in the ſection, is that by which the tube is kept perfectly immoveable with reſpect to the middle of the caſe; while it is unconfined longitudinally in the cavities lined with broad-cloth every where elſe.

Both ends of the tube are ground perfectly ſmooth, and truly at right-angles to the axis of the bore. That end, which in meaſuring uſually lies towards the left-hand (ſince moſt people will work the ſcrew with the right) projects about ſeven-tenths of an inch without the caſe, and is called the fixed end, becauſe the apparatus belonging to it is fixed. The other end towards the right-hand projects about nine-tenths of an inch, and, having a moveable apparatus, is called the moveable end.

The fixed apparatus conſiſts of a cork about three inches in length, made of the very beſt material, and ſo nicely fitted to the bore as juſt to admit of being forced into without burſting it. In the middle of the cork a cylindrical braſs tube is placed, whoſe ſides are thin, the inward end thick, and the outward end open. It receives a ſteel pin, whoſe inward end being formed into a ſcrew, is thereby fixed into the thick metal of the tube. The ſteel pin carries outwardly a button and neck of bell-metal. The neck fits ſo very cloſely the open end of the braſs tube as to prevent any ſhake there; at the ſame time that the inſide of the button applies very juſtly to the ground end of the glaſs tube, to which the outward ſurface (being a true plane) is exactly parallel.

The moveable apparatus conſiſts, like the other, of a cork and braſs tube of the ſame length. Before the inſertion of this cork, an oblong piece ſeven-tenths of an inch long, and two-tenths broad, was cut from it, in that part of its cylinder anſwering to the upper part of the outward end of the glaſs tube, on the inward ſurface of which, about half an inch from the end, a fine line had been previouſly cut by a diamond point. The braſs tube in this cork contains within it a looſe ſteel worm, or helical ſpring, ſomething leſs than the interior diameter of the tube. Along the cavity formed by the ſpiral, there paſſes a ſteel pin, like that in the fixed end; but it is longer, and has no ſcrew at the inward end, that being nicely ground, ſo as to fit a circular hole in the inward end of the braſs tube, while a triangular bell-metal neck fits one of that figure in the outward end. Thus the pin moves freely backwards or forwards without any ſhake, and preſſes upon the ſteel ſpring, by means of a circular braſs collar, placed for the purpoſe, at the inward end of the neck; while the outward end is attached to a bell-metal button. The outward ſurface of this moveable button is ſpherical, deſcribed on a radius of about two inches; while the inward ſurface, like that at the fixed end, would apply cloſely to the ground end of the glaſs tube, but ſhould not be puſhed ſo far forward as to touch it. A circle and narrow ſlide, cut from a ſolid cylinder of ivory, fitted originally to enter eaſily the glaſs tube, is attached to the inſide of the button by ſmall ſcrews, and permits the neck to paſs through a hole made on purpoſe in the circle. The ſlide is about eight-tenths of an inch long, and has a fine interſection cut upon it near the inward end, made black to render it more conſpicuous. Thus, two rods being brought into contact, and the fixed button of one being preſſed againſt the moveable button of the other, the interſection is thereby puſhed forwards until it coincides with the diamond line on the interior ſurface of the tube; whoſe length is ſo adjuſted, as that, when the coincidence is perfect, the diſtance between the plane ſurface of one button, and the ſpherical ſurface of the other, is exactly twenty feet. The left-hand ſide of the plate repreſents the relative poſitions of the extremities of the firſt and ſecond rods, when the ivory is in coincidence with the diamond line. And the right-hand ſide ſhews the relative ſituations of the extremities of the ſecond and third rods, before the ivory is brought to coincidence with the diamond line, the ſlide being then puſhed out by the action of the ſpiral ſpring within the cork.

Every rod has four wheels, two at each end. They are two inches in diameter, and connected by a common ſteel axis, which riſes and falls in a vacuity prepared for its admiſſion in the mahogany end-pieces, the under part of which vacuity is afterwards filled up.

A braſs ſtrap or bridle, about eight-tenths of an inch broad, paſſes over the top of the caſe, and deſcending down each ſide, bends outwards, ſo as to form a projection for the reception of the wheels, whoſe pivots turn in, but near to the lower end of the bridle, which is kept in its place by means of the two ſide ſcrews working in grooves, and the milled-headed ſcrew at top. This laſt ſerves likewiſe to raiſe or depreſs the wheels at pleaſure.

Each rod has two croſs feet, placed immediately behind their reſpective pair of wheels, extending outwards about 4¾ inches from the center on each ſide. Under their outward extremities, ſmall pieces of hardened ſteel, formed into the teeth of a file, are fixed by means of ſcrews. When the firſt rod has been laid in its true place, by unſcrewing the milled heads, the wheels are ſuffered to riſe; whereby the whole weight is removed from them, and thrown upon the teeth of the files, which then indent themſelves into the ſurface of the ſtand, and become as it were united to it. But when the fixed button of the ſecond rod is brought to preſs againſt the moveable button of the firſt, the weight being then thrown upon the wheels by ſcrewing the milled heads at top, the rod is eaſily moved on by the following apparatus.

The three rods are numbered, as were thoſe of deal, 1.2; 3.4; 5.6. On the firſt or odd end of each rod 1. 3. and 5. there ſtands a braſs fork, about two inches high, fixed by four ſcrews and an oblong plate to the top of the caſe. On the ſecond, or even end of each, 2. 4. and 6. there ſtands a braſs pillar of the ſame height with the fork, likewiſe fixed to the top of the caſe by four ſcrews and a circular plate. Two ſteels rods or hooks were indifferently uſed for bringing up the moveable rod (the weight then lying on the wheels) into its true place. They are both repreſented in the plate, and only differ from each other in the ſhape of the braſs milled-headed nuts that work upon the ſcrew, of about 2¼ inches in length, into which the right-hand end of each hook is formed. Thus, while the nut enters very freely into, and reſts upon, the fork, the left-hand end of the hook has a circular hole in it, whereby it ſlips eaſily off and on of the braſs pillar. By referring to the plate, it will appear ſufficiently obvious, from the nature of the nut on the left-hand hook, that it could only move the rod on to coincidence, and could not bring it back again, if the buſineſs happened at any time to be overdone; in which caſe it was neceſſary to move the rod a little backwards by the hand, and then to work anew with the nut, until the coincidence was accurate: whereas the nut on the right-hand hook, having two ſhoulders, could either puſh or pull the rod forwards or backwards: and although this appeared to be an advantage, yet it was found from experience, that it rather bound the hook too much, and occaſioned a kind of ſpring in the parts, which ſometimes diſturbed the coincidence on the removal of the hook; wherefore it was often applied, like the other, by placing the ſcrew itſelf in the fork, and working with both ſhoulders of the nut behind it.

The poſitions of the thermometers, and mahogany oval lid on the top of the caſe, have already been mentioned. This laſt, being unlocked and removed, permits the caſe to be looked into, or the hand to be admitted, in order to be certain that the faſtenings remain ſafe and entire in the inſide. Braſs caps, with the reſpective number of the rods engraved on them, are likewiſe ſcrewed on the male-ſcrews in the ends of the caſe, through which the extremities of the tubes project, to preſerve them from accidents when not in uſe. And, laſtly, to ſtrengthen the caſes, but more particularly to prevent them from being rent when long expoſed to the ſun's rays in the field, the ſides are covered with brown linen laid on very ſmoothly, and carefully glued with thin glue, uſed as a ſtronger kind of paſte, to which it may yet be neceſſary to add a coat of oil paint.

Each of the glaſs rods, completed in the manner above-mentioned, weighs about ſixty-one pounds. Their lengths were aſcertained by means of new braſs points placed in the great plank, the ſpaces of forty inches being laid off, with the utmoſt care, from the braſs ſcale, when the temperature of all had remained for the greater part of two days (Auguſt 15th and 16th) at or very near 68°. For this purpoſe two braſs rectangular cocks, whoſe alternate ſurfaces had been previouſly ground together, were placed upon the plank, ſo as to biſect the extreme dots; in which ſituation they preſented to each other ſurfaces that were truly parallel. The rods being then ſeverally placed between the cocks * (or, as was found to be a better method,

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* The firſt of theſe cocks, or that to which the fixed button was applied, had a hole in it exactly of the height of the center of the button, and large enough to permit the point of the micrometer ſcrew to paſs through it, the ſaid ſcrew being fixed on the farther ſide, or beyond the cock. Thus, while the temperature continued accurately at 68°, the fixed button, or any other plane ſurface, being brought up to the hole in the cock, and the micrometer point ſcrewed ſo far as juſt to touch it, the coincidence continuing in the interim perfect, the exact diſtance of twenty feet was obtained between the point of the ſcrew and the ſecond cock; at which time the diviſion anſwering to the index on the head of the micrometer was carefully noted. This being done, the cock with the hole was removed from the plank, and the rods were ſeverally adjuſted by being placed between the point of the ſcrew and the ſecond cock. This ſubſtitution of the micrometer point, inſtead of the firſt cock, was found neceſſary; becauſe, during the operation of adjuſtment, the temperature would ſometimes change a degree, generally

method, between the point of a micrometer ſcrew, ſupplying the place of the firſt cock, and the ſecond) the ivory interſection was at firſt neceſſarily carried beyond the diamond line, ſo as to make the intermediate ſpace leſs than it ſhould be, until by the gradual grinding down of the moveable bell-metal button, it was enlarged to twenty feet, as then ſhewn by the accurate coincidence of the interſection with the diamond line.

It was by theſe diſtances in the great plank, prolonged to twenty-five feet, that the new length of the ſteel chain was now ſettled, ſo as to obtain the full one hundred feet at four meaſurements. At this time too, braſs points were introduced into the chain at every twenty-five feet, whereby its extent may be compared on any future occaſion; but the temperature had now fallen to 66°½.

Diſpoſition of the Stands for the double meaſurement with the Chain and Glaſs Rods; deſcription of the apparatus then applied to the ends of the Chain; and ultimate continuation of the meaſurement with the Glaſs Rods alone. Tab. XVII. and XIX.

From the various circumſtances already mentioned, in the courſe of this tedious, yet neceſſary recital, it had been for a conſiderable ſpace of time foreſeen, that the reſult given by the meaſurement with the deal rods muſt be entirely rejected,

generally in exceſs, from handling the inſtruments. One degree of alteration, producing a difference of about $\frac{1}{1000}$th part of an inch in the twenty feet, was very eaſily and accurately allowed for by ſuch a micrometer as this, which ſhewed the coincidence of the ivory interſection with the diamond line to be more or leſs perfect, when the head of the ſcrew was moved two diviſions, that is to ſay, $\frac{2}{10000}$ths or $\frac{1}{5000}$th part of an inch.

and that by the glaſs rods adhered to, as every way deſerving of the preference; becauſe of the obvious impropriety there would be, in taking a mean between one indiſputably good and another leſs perfect, however ſmall or trifling in reality the difference of the two might ultimately be found, on a minute and ſcrupulous compariſon.

In order, therefore, to avoid any repetition of the operation with the glaſs rods, and at the ſame time to give ſomething like a fair trial to the chain, it was propoſed, that a double meaſurement ſhould be carried on with both at once; that is to ſay, that the number of ſtands, and ſeveral other parts of the apparatus, ſhould be ſo far augmented, as to admit the chain to be placed twice in advance, and then the rods to follow in ſucceſſion on the ſame ſtands. Accordingly, the various articles having been ſent to the north-weſt end of the baſe on the evening of the 17th of Auguſt, the operation of the double meaſurement commenced next morning the 18th.

By referring to tab. XVII. it will be ſeen, that ſeventeen ſtands were neceſſary for ſupporting the chain, the apparatus attached to each end of it, and ten coffers, whereof every five made about ninety-eight feet, in order that one length of the chain being meaſured off in the firſt five, it might be drawn forward into the laſt five, and ſo on. Theſe ſeventeen ſtands were diſpoſed of in three groups of three each, and four intermediate, between the central and extreme groups. The middle or ſlide ſtand of each group (ſo diſtinguiſhed becauſe ſome of them had braſs ſlides on their tops) ſupported the handle of the chain, and of courſe received the traces made at the feather-edged pieces of braſs, terminating the beginning and ending of the hundred feet. Thus, there were in all ſix ſtands, intermediate to thoſe in the center of each group that ſupported the ninety-eight feet of coffering, which was kept ſo much ſhort of the hundred feet, that its extreme parts might not reſt upon, or even touch, the central ſtands. To that on the left of the center was attached the apparatus for the firſt or zero end of the chain; and to that on the right of the center was attached the apparatus for the laſt end of the chain. When the ſecond chain length had been meaſured off, the firſt and ſixth of the coffer ſtands of the firſt chain were moved forward to prepare for the third chain; and the four remaining coffer ſtands were raiſed, until their ſurfaces came into the ſame plane with the ſlide ſtands, for the reception of the glaſs rods. The ſpace by which theſe ſtands were raiſed was about three inches; for ſo much higher was the ſurface of the interſole or flooring of the coffers than the ſtands which ſupported them.

The apparatus attached to the firſt end of the chain, or that which ſerved to pull it back to the point of commencement, while a weight continued ſuſpended at the farther end, conſiſts of two parts, as may be ſeen by referring to the left-hand ſide of tab. XVII. Firſt, a ſmall wooden frame, fitted to ſlip on to the top of any one of the ordinary ſtands, placed immediately to the left of that which ſupports the handle. Secondly, a flat ſteel rod, about two feet in length, wherein a number of holes are pierced, about an inch aſunder, for the reception of a ſteel pin placed in one of the holes, as beſt ſuits the diſtance of the ſtand from the handle. That end of the ſteel rod neareſt to the end of the chain is formed into a ſcrew about four inches in length, and it receives upon it a forked hook fitted to lay hold of the ſtraight part of the handle of the chain. Within the forked hook there works a ſtrong milled-headed braſs nut, which acting upon the bottom of the fork, the chain is thereby pulled back, until the wire ſuſpending the plummet from the dart on the feather-edge coincides with the point of commencement on the ground underneath; for which purpoſe there is a hole in the top of the ſtand through which the wire paſſes. The apparatus ſtand, thus ſerving to pull back the chain, was commonly loaded with double weights, placed on the two hindermoſt legs.

The apparatus for the laſt end of the chain conſiſts, like the former, of a ſmall wooden frame that can be readily ſlipped upon any of the common ſtands, as may be ſeen by referring to the right-hand ſide of tab. XVII. This frame carries a pulley, over which a rope paſſes having fourteen pounds weight ſuſpended at one end of it, while a forked iron hook at the other end lays hold of the ſtraight part of the braſs handle. By means of theſe two apparatuſes the chain is always kept to the ſame degree of tenſion in its coffers, in each of which a thermometer was placed to indicate the temperature; the whole being covered up from the direct rays of the ſun by a narrow piece of linen cloth, ſtretched along it from one end to the other.

Each coffer conſiſted of three boards about half an inch thick. The ſides were about five inches deep, nailed at the middle to an interſole bottom of four inches, in ſuch manner as to be repreſented in ſection by the letter H. They were ill made, being by their parallelogram ſhape apt to warp, which might have been prevented by giving them the figure of the caſes of the glaſs rods, that is to ſay, making them wide in the middle and narrow at each end.

We are now to proceed to give ſome account of the double meaſurement with the chain and glaſs rods; wherein it muſt be remembered, as alſo in continuing the operation with the glaſs rods alone, that in referring to the map for the daily progreſs in the work, we are going from the forty-ſixth towards the firſt ſtation; and in having recourſe to the general table of the baſe, for altitude, temperature, or correction for expanſion, we are aſcending from the bottom towards the top, contrarily to the order in which the operation with the deal rods was conducted.

On the morning of the 18th of Auguſt, the ſtands with the various parts of the apparatus being placed in the manner juſt now deſcribed, the operation was begun by bringing the firſt end of the chain to coincide with the interſection on the tripod, anſwering to the end of the 1370th deal rod, and 4.31 feet diſtant from the center of the pipe terminating the north-weſt extremity of the baſe. The chain being ſtretched along its five coffers by the fourteen pounds weight ſuſpended over the pulley at the farther end, and the temperatures of the five thermometers being regiſtered in a book kept for that purpoſe, a fine trace was made on a piece of card faſtened under the feather-edge at the farther handle, denoting the end of the firſt hundred feet. The chain being then moved on into the next five coffers, thoſe that had been thus vacated were carried forward to prepare for the third chain length, and thereby permit the firſt ſet of ſtands to be elevated for the reception of the glaſs rods; and ſo in ſucceſſion with the others.

In this manner we proceeded, and in the courſe of the day were only able to meaſure the length of ten chains, or 1000 feet, being the forty-ſixth and forty-fifth hypothenuſes of the baſe, the firſt of 400 and the laſt of 600 feet. Being arrived at this point it was found, that the fine line on the braſs ſlide, marking the extremity of the tenth chain, fell ſhort of another fine line on the ſame ſlide, denoting the end of the fiftieth glaſs rod, juſt two-tenths of an inch. Now it will appear hereafter, when we come to ſhew, by the experiments with the pyrometer, what the real contractions of the chain and glaſs rods were, for the degrees of difference of temperature* below that in which their reſpective lengths were laid off, that this ſmall apparent difference of two-tenths of an inch, between the two modes of meaſuring the thouſand feet, ſhould have been 0.17938 in. to have made the two reſults exactly agree, which is a real difference of only 0.02062 of an inch. Suppoſing then every thouſand feet of the baſe to have been meaſured by the chain with the ſame attention, and conſequently with the ſame, or nearly the ſame ſucceſs (and there ſurely cannot be any reaſon to doubt of the practicability) we ſhall have 27.404 × 0.02062 in. = 0.565 in. or a defect of ſomething more than half an inch on the whole length of the baſe.

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* When the length of the chain was laid off, the heat was $66^\circ\frac{1}{2}$, and that of the glaſs rods 68°. They will, therefore, only agree with each other accurately in theſe reſpective temperatures. The mean of twenty thermometers for the four chain lengths of the forty-ſixth hypothenuſe gave a heat of 61°.6; and for the ſix chain lengths of the forty-fifth, the mean of thirty thermometers gave 59°.75. The temperature of the 400 feet of glaſs by the mean of forty thermometers was 65°.3; and of the 600 feet, by the mean of ſixty thermometers, it was 60°.8. Now, from theſe data, and the expanſions of ſteel and glaſs, as determined by the pyrometer, the computation will ſtand as follows:

$$\begin{array}{llllll}
 & & \overset{\circ}{}\quad\overset{\circ}{} & \overset{\circ}{} & \text{In.} & \text{In.} \quad\quad\quad \text{In.}\\
\text{Steel} & \left\{\begin{array}{l} 400 \\ 600 \end{array}\right. & \begin{array}{l} 66.5-61.6 \\ 66.5-59.75 \end{array} & \begin{array}{l} =4.9 \\ =6.75 \end{array} & \begin{array}{l} \times 0.03052 \\ \times 0.04578 \end{array} & \left.\begin{array}{l} =0.14955 \\ =0.30901 \end{array}\right\} =0.45856 \left\{\begin{array}{l} \text{contract.} \\ \text{of 1000} \\ \text{feet.} \end{array}\right. \\
\text{Glaſs} & \left\{\begin{array}{l} 400 \\ 600 \end{array}\right. & \begin{array}{l} 68.0-65.3 \\ 68.0-60.8 \end{array} & \begin{array}{l} =2.7 \\ =7.2 \end{array} & \begin{array}{l} \times 0.02068 \\ \times 0.03102 \end{array} & \left.\begin{array}{l} =0.05584 \\ =0.22334 \end{array}\right\} =0.27918 \left\{\begin{array}{l} \text{contract.} \\ \text{of 1000} \\ \text{feet.} \end{array}\right.
\end{array}$$

$$\begin{array}{ll}
\left.\begin{array}{l} \text{The 1000 feet of ſteel ſhould have contracted more than} \\ \quad\text{the 1000 feet of glaſs, - - -} \end{array}\right\} & =0.17938 \\
\text{But the difference was found to be - -} & =0.20000
\end{array}$$

Therefore the error of the chain in defect was - 0.02062 × 27.404 = 0.565 in. or little more than half an inch on the whole baſe.

So nice an agreement between two reſults, with inſtruments ſo very different, could not fail to be conſidered as aſtoniſhing; and as it rarely happens, that the graduation of thermometers will ſo nearly correſpond with each other, as not to occaſion a much greater error, all were very deſirous that it could have been farther confirmed by continuing the operation in the ſame way through a more conſiderable proportion of the whole length. But beſides the tedious nature of the double meaſurement, owing to the multiplicity of ſtands, platforms, coffers, and other articles, that were now ſucceſſively to be moved forward, and for which purpoſe it had been found neceſſary to re-inforce the party of ſoldiers with ſix additional men; the operation had already trained out to a much more conſiderable length than had been expected; the ſummer was now far advanced, and the continuance of good weather uncertain; the coffers likewiſe for the chain, having been conſtructed in a hurry, were found to be defective: in ſhort, all theſe reaſons contributed to induce us to give up, for the preſent, any farther experiment with the chain, and to proceed with the glaſs rods alone in the completion of the meaſurement.

Accordingly, on Thurſday the 19th of Auguſt, the operation with the glaſs rods was continued for the five hypothenuſes, from the forty-fourth to the fortieth incluſive. It will be remembered, that in proceeding with the deal rods, double pickets had been placed in the ground, at the middle of the forty-firſt hypothenuſe, or that point which terminated the 1215th rod, reckoning from the ſouth-eaſt, or the 155th from the north-weſt end of the baſe. Now, in returning to this point with the glaſs rods, the extremity of the 155th fell ſhort of the ſilk thread ſtretched from picket, to picket, juſt one-tenth of an inch. The expanſion of the braſs ſtandard ſcale, and that of glaſs being taken into the account, it appears, that the ſmall expanſion * of the deal rods from the humidity of the air, muſt, at this point, have exceeded what it was eſtimated at in the general table by 0.931 of an inch, ſuppoſing no error of any kind whatever to have ariſen in the execution, from bringing the rods into contact, or otherwiſe.

On Saturday the 21ſt of Auguſt, the meaſurement was reſumed at the thirty-ninth ſtation, and continued for five hypothenuſes to the thirty-fifth incluſive.

This day, about noon, HIS MAJESTY deigned to honour the operation by HIS preſence, for the ſpace of two hours, entering very minutely into the mode of conducting it, which met with HIS gracious approbation.

On Monday the 23d, the menſuration was farther continued for five hypothenuſes, that is, to the thirtieth incluſive.

On Tueſday the 24th, we proceeded with the meaſurement for the ſpace of ſeven hypothenuſes, finiſhing the buſineſs of the day at the twenty-ſecond ſtation.

* 155 deal rods = 3100 feet {
In.
+0.383 for 1° exceſs of temperature of the braſs ſcale from 62° to 63°.
+0.651 proportionable part of the eſtimated expanſion from humidity.

+1.034 equation of the deal rods on 3100 feet.

155 glaſs rods = 3100 feet {
+2.301 for 6° exceſs of the heat of the braſs ſcale from 62° to 68°.
−0.436 obſerved contraction of the glaſs from the 11th and 12th columns of the table.
+0.100 by which the 155th rod fell ſhort of the thread.

+1.965 equation of the glaſs rods on 3100 feet.

0.931 { Difference of the two equations, under-rated in the expanſion of the deal rods.

It will be remembered, that in carrying on the operation with the deal rods, double pickets were left in the ground at the twenty-ſeventh ſtation, anſwering to the extremity of the 810th rod from the firſt, or the 560th from the laſt end of the baſe. Now, on arrival at this point, the 560th glaſs rod overſhot the ſilk thread, ſtretched from one picket to the other, 2.525 inches. Here again we find, that the lengthening * of the deal rods from the moiſture of the atmoſphere differs but little from what it has been eſtimated at by compariſon with the ſtandard, being over-rated only two-tenths of an inch on the 560 rods. In this day's operation, in paſſing the bridge laid over the old river, the meaſurement, inſtead of being made in the hypothenuſal, was carried on in the level line, for the ſpace of twenty rods, namely, fifteen rods of the twenty-ſeventh, and five of the twenty-ſixth hypothenuſe; which occaſions the alteration in the reduction of theſe two ſpaces, marked with aſteriſks in the general table.

As ſome trouble had been found to attend the croſſing of the great road, in the firſt meaſurement, owing to the number of carriages that were continually paſſing, the depth of

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	In.	
* 560 deal rods = 11200 ft.	+ 1.390	for 1° exceſs of heat of the braſs ſcale from 62° to 63°.
	+ 5.258	eſtimated expanſion from moiſture,
	+ 6.648	equation of the 560 deal rods.
560 glaſs rods = 11200 ft.	+ 8.343	for 6° exceſs of heat of the braſs ſcale from 62° to 68°.
	+ 1.821	obſerved expanſion of glaſs } from columns 11th and 12th.
	− 1.191	obſerved contraction of ditto } from columns 11th and 12th.
	− 2.525	over-ſhot the ſilk-thread.
	+ 6.448	equation of the 560 glaſs rods.
	0.200	Difference over-rated in the expanſion of the 560 deal rods.

the ditches, and height of the banks of the old Roman way; therefore treſſels, ſuited for the purpoſe, had been now prepared: and leſt any accident might have happened in conducting this part of the operation, ſo as to oblige us to a repetition, double pickets were placed in the uſual manner in the ground two rod lengths from the twenty-ſixth ſtation, to which we could have referred, without going back as far as the tripod left at the twenty-ninth ſtation, the point from which we had departed in the morning.

Bad weather prevented any progreſs being made on the 25th; and, on the 26th, all that could be done was to meaſure the twenty-ſecond and twenty-firſt hypothenuſes.

On Friday the 27th, the work went on more expeditiouſly, having in the courſe of that day meaſured ſix hypothenuſes, and placed the tripod at the fourteenth ſtation.

On Saturday the 28th, eight hypothenuſes were meaſured, and the tripod was placed at the ſixth ſtation. In this day's operation, being arrived near the bridge laid over Wolſey River, double pickets were placed in the ground in the point anſwering to the extremity of the 1172d rod, reckoning from the north-weſt, or the 198th rod from the ſouth-eaſt end of the baſe, that we might recur to them in caſe of accident; and the eighteen rod lengths, between this point and the ſixth ſtation, were meaſured on the level, inſtead of the hypothenuſal line, which required the alteration of the reduction as diſtinguiſhed by the aſteriſk in the general table.

On Monday the 30th of Auguſt, the meaſurement with the glaſs rods was completed*; when the extremity of the 1370th rod over-ſhot the center of the pipe terminating the baſe towards the ſouth-eaſt by 17.875 inches, or 1.49 foot. Hence, when the ſeveral equations for expanſions are reſpectively taken into the account, we find, that the alteration of the deal rods from the humidity of the air, which, by compariſon with the ſtandard, was apparently moſt conſiderable in the firſt and ſecond ſections of the baſe, has now wholly vaniſhed; that is to ſay, the total amount of it has been over-rated by 20.964 inches[*]; and this is the contradictory circumſtance that has been formerly alluded to.

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* The gentlemen who were preſent at, and aſſiſting in, the laſt day's operation were Captain Bisset, Mr. Greville, Sir William Hamilton, Mr. Lloyd, and

I have already ſuggeſted what appear to me to have been the only three poſſible cauſes of this difference, found between the eſtimated and real expanſion of the deal rods; and as we are to abandon that meaſurement entirely, it is of little or no importance now to endeavour to diſcover, were it poſſible, whence it may have ariſen. If any error was actually com-

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and Dr. Usher, Profeſſor of Aſtronomy in the College of Dublin. This laſt gentleman was ſo obliging as to obſerve, with the moſt ſcrupulous attention, throughout the whole operation with the glaſs rods, that the coincidence of the ſecond with the firſt remained undiſturbed, while that of the third with the ſecond was completing.

[*]

	In.	
1370 deal rods = 27400 ft.	+ 3.389	for 1° of the braſs ſcale from 62° to 63°.
	+ 24.223	eſtimated expanſion from humidity.
	+ 27.612	equation of the 1370 deal rods.
1370 glaſs rods = 27400 ft.	+ 20.336	for 6° of the braſs ſcale from 62° to 68°.
	+ 5.989	obſerved expanſion of glaſs } from columns 11th and 12th.
	− 1.802	obſerved contraction of ditto } from columns 11th and 12th.
	− 17.875	ſpace by which the 1370th rod over-ſhot the pipe.
	+ 6.648	equation of the 1370 glaſs rods.
	20.964	over-rated in the total expanſion of the deal rods.

mitted, which is the leaſt of all probable, it could only have happened at the place of the tripod, by bringing a wrong point of the ſtem over it when the operation was reſumed. But it is well known, how much care and pains were taken to prevent any thing of that ſort. Indeed the hypothenuſal diſtances, as given by the chain, agreed ſo nearly among themſelves, that even a foot or ten inches would have made ſo remarkable a difference in the ſituation of the next picket as could not have paſſed unobſerved. Beſides, in returning with the glaſs rods, after paſſing the Staines Road, the meaſurement was gradually found (without any leap whatever) to over-ſhoot the pickets, and at laſt over-reached the ſouth-eaſt pipe by 17.875 inches. I am therefore inclined to believe, that the difference ariſes partly from what may have been loſt by conſtantly butting one rod againſt the other, whereby the end of the 1370th did not reach ſo near to the north-weſt pipe as it ought to, and would have done, if the rods had been applied to each other by coincident lines. It muſt, however, be confeſſed, that the near agreement between the glaſs and deal rods in the upper part of the heath ſeems not perfectly reconcileable to this ſuppoſition. Nevertheleſs, the deſcent being quickeſt, and the irregularities of the ſurface much more conſiderable in the lower than the upper part, might produce ſome effect in one which did not take place in the other. But the chief part of the difference I take to have proceeded from over-rated expanſion; that is to ſay, the rods, when brought into uſe, contracted ſooner than we imagined, and thereby gave a ſhorter meaſure than what was aſſignable to them from the mean of any two or more compariſons.

The laſt day of Auguſt was employed in diſcharging the party, and removing the various parts of the apparatus to Spring-Grove Houſe.

Deſcription of the Microſcopic Pyrometer, made uſe of for determining by experiment the expanſion of the metals concerned in the meaſurement of the Baſe. Tab. XX.

Having, in the preceding part of this Paper, given a very minute account of the actual operations in the field, that the Public, being thus informed of every circumſtance, might be the better enabled to judge of the accuracy of the reſult, it remains yet to point out, in what manner the equations for the expanſions of the ſtandard ſcale, ſteel chain, and glaſs rods, applied to the apparent meaſurement of the baſe, in ſeveral of the preceding notes, have been obtained by means of experiments with the pyrometer.

It is ſufficiently well known, that many years ago, a very ingenious and valuable Member of this Society did publiſh in the Philoſophical Tranſactions (vol. XLVIII. 1754, N° 79.) an account of experiments made with a pyrometer of his invention. No doubt was entertained of the accuracy of the experiments here alluded to; on the contrary, they will be confirmed by the account now to be given of theſe recently made, with which they very nearly agree. But as different pieces of metal of the ſame kind are certainly ſuſceptible of different degrees of expanſion, it was judged beſt, on the preſent occaſion, to put rods to the teſt of thoſe very metals that had been made uſe of in the actual meaſurement of the baſe.

For, ſuppoſing both ſets of experiments to have been made with inſtruments equally perfect, and to have been in other reſpects equally well conducted, this muſt always be conſidered as the moſt unexceptionable method. Beſides, the expanſion of rods of the length of five feet being aſcertained, the unavoidable error of obſervations of this delicate nature, becomes leſſened in proportion to the exceſs of their length above ſhorter rods. In theſe new experiments too, another ſort of pyrometer, invented by Mr. RAMSDEN, has been applied, of ſuch accurate conſtruction that it ſeems not eaſy to improve it.

The microſcopic pyrometer, ſo named becauſe, by means of two microſcopes attached to it, the expanſion is meaſured, conſiſts of a ſtrong deal frame five feet in length, nearly twenty-eight inches broad, and about forty-two inches in height. The elevation of the eye-piece ſide, or that which preſents itſelf to the obſerver, and alſo of the micrometer end, or that which is towards his right-hand, as well as the general plan of the top, are repreſented by a ſcale of one inch to a foot, or one-twelfth part of the real dimenſions, in tab. XX. where likewiſe may be ſeen the angular view of the fixed end, together with plans, ſections, and elevations, of ſeveral of the principal parts, done to larger ſcales. From theſe, it is hoped, the conſtruction of the machine will be eaſily underſtood, without entering into a minute deſcription of the almoſt numberleſs ſmaller parts whereof it is compoſed.

On the top of the frame, two deal troughs, upwards of five feet in length, are firmly ſcrewed. That towards the obſerver overhangs the frame ſomething more than an inch: that on the farther ſide is even with the back part. Each of theſe troughs, which are about three inches ſquare in the inſide, contains a caſt-iron ſtandard priſm, whoſe ſides are 1¼ inch.

The manner in which the priſms are faſtened to the bottoms of their reſpective troughs, and the nature of the apparatuſes they carry on their extremities, will be readily conceived, by referring to the particular plans and elevations of them, comprehended in the group of eight ſmall figures towards the right-hand of the general plan. Four of theſe appertain to the left-hand or fixed microſcope; and the other four to the right-hand or micrometer microſcope, ſo diſtinguiſhed becauſe it has a micrometer attached to it. By means of the braſs collars which embrace the priſms, their left-hand or fixed ends are ſcrewed down extremely faſt to the braſs pieces whereon they reſt, ſo as to be perfectly immoveable there with regard to their troughs; whereas their right-hand ends are kept eaſy, yet without ſhake, in their collars, that they may contract or lengthen freely as the temperature may require, without occaſioning any ſtrain upon the parts. The priſm in the neareſt trough may be called the eye-piece priſm, becauſe it carries the eye-pieces of the microſcopes; and that in the farther trough, the mark priſm, becauſe it carries the marks or croſs wires at which the microſcopes reſpectively point. The troughs are covered with pitch in the inſide, to make them hold water; and each has a cock in the left-hand end for diſcharging it.

Between the two deal troughs, one of copper, as a boiler, is placed, ſomewhat ſhorter than the former, but ſtill upwards of five feet in length. It is about 2¾ inches broad, and 3½ in depth. The center of the boiler, or rather the center of the object lens which ſtands in it, as we ſhall have occaſion ſoon to point out, is diſtant from the croſs wires of the mark 5.81 inches; and from the wires of the micrometer attached to the correſponding eye-piece 20.33 inches. The boiler reſts on five ſmall rollers, one being fixed to each end of the frame, and the other three to the braces which run acroſs it. This copper trough has likewiſe a cock in the left-hand end; and in the general plan a caſt iron priſm is repreſented in it; but this laſt carries no apparatus, as thoſe in the wooden troughs do, being exactly of the length of five feet, and only placed there as one of the rods whoſe expanſion was tried, and to ſhew that the machine was capable of receiving a rod of that weight and magnitude.

By referring to the general plan it will be ſeen, that twelve lamps are made uſe of to bring the water in the copper to boil. They ſtand on four ſhelves, three in each compartment formed by the croſs braces of the frame. They can readily be puſhed forwards or drawn backwards, and when actually in uſe, their handles are only ſeen, projecting from under the copper. It was found, by burning oil in the lamps, the heat of the water could not be raiſed above 209° or 210°; but with ſpirits of wine it was brought into violent ebullition. The plan of the frame likewiſe ſhews, that the tubes of the microſcopes are ſub-divided into ſeveral diſtinct parts; and that one of theſe parts is attached by a collar to a mahogany priſm, which reaches from one end to the other. But the uſe of theſe contrivances it will be beſt to defer ſpeaking of, till after having deſcribed the apparatuſes that are placed within the copper boiler.

At the bottom of the plate the boiler is repreſented, both in plan and longitudinal ſection, to a ſcale of one-fourth part of its real dimenſions. It contains within it two braſs ſlides, the one long and the other ſhort; which, from the braces that bind the cheeks together, very much reſemble the form of a ladder. The long ſlide, whoſe cheeks are 1¼ inch deep, reaches almoſt the whole length of the copper, although every where unconnected with it except at the points A and B. At the firſt of theſe, two ſtrong pieces of braſs, fixed to the cheeks, and notched underneath, embrace the ends of a braſs cylindrical bar faſtened to the bottom. At the laſt, the cheeks of the ſlide reſt on a roller. Whence it follows, that the copper and ſlide remain immoveable with regard to each other at A; but from thence, towards either end, they have full liberty to change place; that is to ſay, to expand by heat, or contract by cold, in any proportion their different natures may require. The left-hand end of the ſlide is ſhut up by a ſtrong perpendicular piece of braſs, connected with the two ſide rings which ſupport the object lens of the fixed microſcope, whoſe center correſponds accurately with its inward face. This piece being firmly ſcrewed to the cheeks of the ſlide, and counter-arched outwardly, forms a ſtrong butt for the fixed end of the expanding rod (ſuppoſed here to be the ſteel bar) to act againſt. Within the right-hand end of the long ſlide, reſts a ſhort one of about 14½ inches in length, whoſe cheeks are 1¼ inch deep. Its outward end, at C, reſts on the cylindrical ſurface of the laſt brace of the long ſlide, fitted purpoſely to receive it; while a narrow longitudinal bar fixed in its inward end, at DE in the ſection, moves freely in the notch of a bridge F, framed for it in the long ſlide. The outward end of this ſhort ſlide is ſhut up in a ſimilar manner with the oppoſite end of the long one. This end-piece is alſo connected with the two ſide rings which ſupport the tube containing the object lens of the micrometer microſcope, whoſe center is perpendicularly over its inward face, and being fortified outwardly by an edge bar, it forms a butt for the expanding end of the rod that is in experiment to puſh againſt. By attending to the plate it will be perceived, that to this end of the boiler a braſs tube (R) is fixed, which contains within it a braſs rod, ſurrounded by a helical ſteel ſpring; which acting upon a broad ſhoulder of the rod prepared for the purpoſe, thereby preſſes its inward end, which enters the boiler, againſt the perpendicular ſurface of the end-piece of the ſhort ſlide. Thus, the farther end of the rod in experiment, ſuppoſed now to be in its contracted ſtate, is conſtantly made to bear againſt the ſurface that is under the fixed microſcope. But on the application of heat, the irreſiſtible force of expanſion in the rod obliges the ſpring to give way; the ſhort ſlide changes its place, and with it the object lens of the micrometer microſcope moves on a ſpace proportionable to the degree of heat that is applied; and it is this diſtance, meaſured by means of the micrometer, as hereafter will be ſhewn, that determines the quantity of expanſion, or the ſpace by which the rod has lengthened. From the plate it will be further obſerved, that the rod in experiment reſts on the ſurfaces of three rollers, about an inch in diameter; and by means of three pair of milled-headed nuts 1½ inch in diameter, which move on axes that are formed into ſcrews, until they almoſt touch the ſides of the rod, this is kept in its true central poſition, whatever may be its form or lateral dimenſions.

The microſcope towards the left-hand has been denominated fixed, becauſe it correſponds with the firſt or fixed end of the rod in experiment, and never changes its place while theſe are of the length of five feet. But it appearing to be of conſequence, that the expanſion of the ſtandard braſs ſcale, which is not quite forty-three inches long, ſhould be determined, the pyrometer has therefore been adapted for the reception of any rods leſs than five feet, whereby it is made more univerſally uſeful. For this purpoſe it becomes neceſſary to move the marks and eye-pieces of the fixed microſcope, along their reſpective priſms, to the proper poſition for the rod that is to be tried. Nevertheleſs the object lens remains in its original place; and in its ſtead another lens, of the ſame focal diſtance, is fixed on a ſimilar end-piece, that can be firmly clamped to any correſponding place whatever of the cheeks of the long ſlide. Hence will appear the reaſon for breaking the ſcreening tubes of the microſcopes into ſeveral parts, and the uſe of the mahogany priſm, along which the thick part of the tube moves from one end to the other.

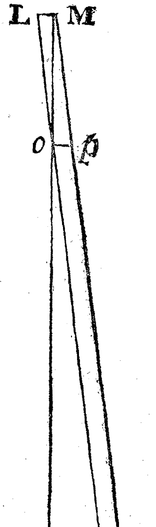
The pyrometer, ſince it was firſt made and tried, has undergone ſeveral ſmall alterations, by way of improvements, which it is now unneceſſary to deſcribe particularly. One of theſe was the application of croſs levels to the parts of the tube (SS in the general plan) connected with the object glaſſes. The manner in which they are fixed on will appear from the repreſentations of them in the lowermoſt left-hand angle of the plate. And the ſection at the right-hand angle ſhews the appearance of the double braſs hook, univerſal joint, and milled-headed nut, applied acroſs the middle of the boiler (at TU) whereby the levels are brought to be conſiſtent, when the water is boiling, with the poſition they had been adjuſted to when the temperature was at freezing; that is to ſay, they are kept parallel to themſelves in both ſtates. This was thought neceſſary, becauſe the application of the boiling water ſunk the middle of the ſlide a ſmall matter, and thereby made the levels run outwards.

The micrometer ſo often mentioned, being a very eſſential part of the machine, is repreſented both in elevation and horizontal ſection to the full ſize. Its chief parts conſiſt of a micrometer ſteel ſcrew, which works in the ſquare nut of a braſs ſlide, while the plane part of it enters into a long braſs ſocket, nicely ground to receive it, and thereby preventing all ſhake. To the ſquare nut, one end of a watch chain is attached; the other end having paſſed around is fixed to a barrel, which contains a watch ſpring coiled up in the uſual manner. By this contrivance, any loſs of time in the motion of the moveable wire, fixed to the ſquare ſlide, is effectually prevented, whether the ſcrew be turned backwards or forwards. The fixed wire, ſo called becauſe it is only made uſe of occaſionally, appears in the elevation to the left-hand of the former, and is farther removed from the obſerver, being attached to the oval ſlide which bounds the field of the micrometer. This wire is moved by the inſertion of a milled-headed key (although not repreſented in the plate) fitted to ſlip upon the ſquare end of its proper ſcrew, which may be ſeen, in the elevation, projecting above the micrometer head. It has but little motion, being only intended for the meaſurement of ſmall differences of expanſion, or any ſmall ſpace, by leaving it there, while the other wire is repeatedly brought to coincide with, and again depart from it. For particular purpoſes this wire may be uſeful; nevertheleſs, the inſtrument would have performed very well without it.

The conſtruction of the microſcopes will be readily underſtood, by referring to the figures under that head on the right-hand ſide of the plate; where the relative ſituations of the different eye-glaſſes, with regard to the wires or place of the magnified image, as well as to the eye, are truly repreſented in their real dimenſions; but the diſtances from theſe to the object lenſes and marks reſpectively, are contracted or broken off, from want of ſufficient room to delineate them otherwiſe. To increaſe the angle of viſion in microſcopes, it is always neceſſary that they ſhould have at leaſt two eye-glaſſes, and the fixed microſcope in the plate ſhews them in their uſual poſition, the image from the object lens there being formed between the two, that the diſperſion of rays in the firſt may be corrected by that of the ſecond. But although this conſtruction ſerves perfectly well every purpoſe of the fixed microſcope, yet it could not anſwer in the moveable one, to which the micrometer is attached, where equal parts of an image, or their motion, are to be meaſured by the equable motion of the object lens, as ſhewn by the micrometer: for in that caſe, the interpoſition of an eye-glaſs before the image was formed, would not only have diminiſhed its ſize, and thereby rendered the meaſure leſs accurate; but likewiſe, by refracting the oblique pencils more than thoſe nearer the center, it would have deſtroyed the equality of the ſcale, and made equal parts of the object itſelf to have been repreſented unequally in the magnified image, and conſequently erroneouſly meaſured by unequal parts of the micrometer. It was to remedy a defect of this ſort that Mr. RAMSDEN propoſed his new ſyſtem of eye-glaſſes, deſcribed in the Philoſophical Tranſactions, vol. LXXIII. 1783, Nº 5. And he has here applied that ſyſtem in the conſtruction of the micrometer microſcope; where it will be perceived, that both glaſſes ſtand between the eye and the image, whereby the greater magnitude of this laſt is obviouſly preſerved, as well as the juſt ſimilarity of all its parts to thoſe of the object itſelf.

With regard to the ſcale of the pyrometer, it is, in the firſt place, to be obſerved, that the head of the micrometer ſcrew, which is nine-tenths of an inch in diameter, is divided into fifty equal parts, each of which being reckoned two, it is therefore numbered to 100. Fifty-five revolutions of the head, being equal to 0.77175 of an inch, as meaſured with great accuracy by Mr. RAMSDEN's ſtraight-line engine, it follows, that there are 71.27 threads of the ſcrew in an inch; that ſeven revolutions and nearly $\frac{13}{100}$th parts move the wire of the micrometer one-tenth of an inch; and that $\frac{1}{100}$th part of a revolution, or half a diviſion, anſwers to a motion of ſomething more than 0.00014 of an inch.

Having thus obtained the number of revolutions and parts of the micrometer (7.13) correſponding to one-tenth of an inch at the wires, it is ſufficiently obvious, that the number anſwering to one-tenth LM at the mark being likewiſe obtained, and added to the former, their ſum will give the meaſure of one-tenth at the object lens, or the ſpace by which the expanding rod has lengthened, as ſhewn by the motion of the lens from *o* to *p*. This meaſure of one-tenth of an inch at the mark was aſcertained in two different ways, and the reſults exactly agreed with each other. In the firſt place, a very thin ivory ſlide, whereon ſeveral twentieths of an inch were nicely divided by exceeding fine lines, was prepared, and made to move in the mark where the braſs ſlide now exiſts. A candle being then placed behind it at night, while the pyrometer ſtood within doors, and the micrometer wire being repeatedly moved by the ſcrew, its coincidence with the lines was diſtinctly ſeen through the ivory; whereby two of the ſpaces were found to be meaſured by 24.93 revolutions of the head. The ſecond method was, by means of two exceeding fine wires placed parallel to each other on the braſs ſlide, where they now remain, at the diſtance of one-twentieth of an inch on each ſide of the interſection wires, as may be ſeen by obſerving the real mark, or rather its magnified image, as ſhewn in the oval field of the micrometer, in the central figure of conſtruction. The revolutions of the micrometer anſwering to the diſtance between theſe parallel wires was, as before, found to be 24.93; which being added to 7.13, we have 32.06 for the number of revolutions meaſuring a motion of one-tenth at the object lens, or the expanſion of one-tenth. In this manner Mr. RAMSDEN obtains the ſcale of his pyrometer in the eaſieſt and moſt ſimple way imaginable, without any neceſſity for knowing the abſolute diſtances of the object lens from the wires of the mark on one hand, and thoſe of the micrometer on the other; diſtances not eaſily aſcertained by actual meaſurement, on account of the poſition of that glaſs in its cell, which cannot conveniently be come at. Thus, in tab. XX. as well as in the annexed figure, LM being the object at the diſtance of the mark, equal to one-tenth of an inch; then *ml* will be its magnified image, in proportion to the former as *mo* is to *o*M. And, if through the point *p*, the place to which the object lens *o* has been carried by the motion of the expanding rod, a line M*q* be drawn parallel to L*l*, we ſhall have $ml = 24.93 + lq = 7.13 = mq = 32.06$, the number of revolutions of the micrometer meaſuring *op* the expanſion. Having thus obtained the total number of revolutions correſponding to *mq*; and having likewiſe meaſured the total diſtance *m*M = 26.144 inches, a ſpace eaſily aſcertained between the wires of the micrometer and thoſe of the mark, the partial diſtances *mo* and *o*M may then be readily found by computation: for $mq : ml :: mM : mo =$ 20.33 inches; and $mq : mM :: op : oM =$ 5.814 inches.



In order to finiſh the deſcription of the pyrometer, it is only neceſſary to obſerve farther, that the circular ſcale, ſeen in the elevation of the micrometer, whoſe zero appears to coincide with the dart on the plane part of the braſs, is that which ſerves by its motion to regiſter the turns of the head. A forked key, fitted to enter the holes near the circumference of the circle, is made uſe of for the adjuſtment of this zero. The circle ſhould never be turned backwards or towards the left, leſt the watch chain ſhould thereby be thrown off the barrel, but always forwards or towards the right, even if it ſhould be neceſſary to move it almoſt an entire revolution. The zero of the head is that which ſhould be firſt brought to correſpond with its proper dart. They may be ſeen to coincide in the horizontal ſection of the micrometer; and the departure of zero from this dart, indicates, by the number of diviſions that are intercepted, the value of any fractional part of a revolution.

Account of the experiments with the Pyrometer.

Although the inſtrument which I have here endeavoured to deſcribe was begun early in the winter of 1784, yet it was not finiſhed till the beginning of laſt April; at which time it was brought to Argyll-Street, and being placed truly level on the ſtone pavement of the yard, was covered with an oil-cloth canopy, that the experiments might not be interrupted by rainy weather.

To fill the three troughs completely it required from twenty-five to thirty pounds of pounded ice, which was always put in with great care, ſo as to apply as compactly as poſſible to the ſtandard priſms and rod reſpectively, with but little common water* at firſt added; it having been found in theſe experiments, that ice water only, ſuch as drains from the ice itſelf, is that which ſhould properly be made uſe of to mix with the pounded ice, in order to bring the whole maſs to the true freezing temperature. Being at the commencement uncertain what time might be neceſſary for the rods, eſpecially when of ſo large a ſize as the ſtandard priſms, to acquire the juſt temperature of freezing, at firſt the ice was put into the troughs over night, to prepare for the continuation of the experiment next morning. But after many repeated trials, this precaution was found to be needleſs; a quarter of an hour being more than ſufficient to give to all the freezing temperature, as well as to render the lens on the expanding rod ſtationary, after the water ſupplying the place of the ice had been brought fairly to boil.

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* When common water was uſed, although not in any very conſiderable proportion, the thermometer kept always half, and ſometimes three quarters of a degree above 32°.

The inſtrument, in its firſt ſtate, having in ſome caſes made the expanſion appear to be progreſſive, and not equable; therefore its rate was attempted to be aſcertained by noting the progreſſion anſwering to 60°, 120°, and 180° above freezing. But when the inſtrument was rendered perfect, and that no ſenſible difference was found between the expanſion at the lower and that at the upper part of the ſcale, a fair mean being taken between its aſcending and deſcending rates, and allowing for the difficulty of keeping the water, for any length of time, preciſely to the ſame intermediate heat; then this tedious mode of conducting the experiments was given up, and the expanſion for 180° was at once determined by bringing the water to boil around that rod, which but a little before had been lying in melting ice, and which the ſtandard priſms ſtill continued to do throughout each experiment, care being taken to have a ſupply of pounded ice always ready to keep theſe two troughs quite full.

Two obſervers are neceſſary for the effectual application of the pyrometer. He who obſerves with the fixed microſcope, takes care that its object lens is kept in its true place, that is to ſay, that the wire in the eye-piece accurately biſects the interſection wires of the mark. This he is enabled to do by means of the apparatus attached to the fixed end of the boiler, as will be beſt conceived by obſerving the plan (at WX) along with the elevation of that end placed near it. The apparatus conſiſts of two milled-headed ſcrews, working in braſs plates faſtened to the end of the frame, and acting againſt a ſmall cock which projects from the lower part of the boiler, whereby this laſt receives ſuch longitudinal motion to and fro on its rollers, as is ſufficient for the adjuſtment of the lens. He who obſerves with the micrometer microſcope, having brought the zero of the micrometer head to its dart, as ſhewn in the horizontal ſection, and alſo the revolution zero to its dart, as repreſented in the elevation, takes care, when the rod has acquired the freezing temperature, that the micrometer wire biſects the interſection wires of its proper mark. This he effects by working with the milled-headed ſcrew, repreſented in the plan and elevation of that mark, whereby the mark itſelf is moved until the biſection is accurate; and during the whole of this time, the firſt obſerver muſt be extremely attentive to keep his lens adjuſted.

One aſſiſtant at leaſt is neceſſary, who takes his ſtation on the oppoſite ſide of the pyrometer, to obſerve the levels, and keep them adjuſted, by means of the double hook applied near the middle of the boiler, and repreſented in the ſection on the line TU, at the lowermoſt right-hand angle of the plate.

The pyrometer having been adjuſted in the manner here deſcribed, by giving ſufficient time for the ſtandard priſms and

rod

rod to contract to the true freezing temperature, as was eaſily known by the wires becoming perfectly fixed and ſtationary with regard to the marks; the ice was then removed from the copper trough; and the ſame being filled with water nearly on the boil, the ebullition was completed, and kept up, by means of the lamps now lighted for the purpoſe, and ſlipped in underneath.

The expanſion, anſwering to the 180° between freezing and boiling, was now meaſured by working with the micrometer ſcrew until the biſection[*] of its wire with thoſe of the mark was again complete; the obſerver at the fixed microſcope taking alſo eſpecial care all the while to keep his biſection perfectly accurate. The number of revolutions, regiſtered by the number of entire diviſions that the zero of the circular ſcale had departed from its dart or index, and alſo the value of any fractional revolution, regiſtered by the diviſions on the head intercepted between zero and its proper dart, were then noted, as expreſſed in the firſt column of the ſubjoined table of experiments; which requires no other explanation than what is therein inſerted, and which has been extended purpoſely to ſhew at one view, from inſpection only, how much the length of our baſe would have been affected, if meaſured by theſe metals reſpectively, in temperatures between 32° and 62°.

All the experiments were repeated at leaſt twice, and ſome of them three times, except the ſtandard ſcale and glaſs pendulum rod, whoſe expanſions were only tried once. The difference of a few diviſions between the mean and extremes on the heat of 180° being, in things of this ſort, of no importance, it was judged wholly unneceſſary to aim at a greater degree of preciſion in repeating them oftener. By referring to the table, particularly that column containing the expanſions on one foot by 180°, it will be perceived, that they are uniformly a ſmall matter leſs than what has been aſſigned to the ſame metals reſpectively, in the experiments formerly alluded to.

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[*] This biſection of the wires may always be made to a great degree of preciſion, by one with a tolerably good eye, and accuſtomed to obſervations of this ſort. I have myſelf repeatedly adjuſted the wires eight or ten times running, allowing another perſon to read off and unadjuſt each time, without the mean difference exceeding one-fourth of a diviſion of the head, which is only $\frac{1}{64000}$th part of an inch.

Ultimate determination of the length of the Baſe on Hounſlow-Heath.

In the former part of this paper, we have had occaſion to ſpeak of the ſeven firſt columns of the general table of the baſe; and the titles at the tops of the others reſpectively ſerve ſufficiently to explain thoſe towards the right-hand; the expanſion of glaſs above, and its contraction below 62°, contained in the eleventh and twelfth columns, being deduced from the recent experiments with the pyrometer.

	Feet.
The hypothenuſal length of the baſe, as meaſured by 1369.925521 glaſs rods of twenty feet each + 4.31 feet, being the diſtance between the laſt rod and the center of the north-weſt pipe, has been ſhewn to be - - -	27402.8204
The reduction contained in the ſeventh column of the general table to be deducted is . .	0.0714
Hence the apparent length of the baſe, reduced to the level of the ſouth-eaſt extremity, becomes	27402.7490

The

	Feet.
The apparent length is to be augmented by the exceſs of the expanſion above the contraction of the glaſs rods, contained in the thirteenth column of the general table = 4.1867 inches, reduced to the heat of 62°, as has been uſually done in former operations of this nature . . .	0.3489
The apparent length is farther to be augmented by the equation for 6° difference of temperature of the ſtandard braſs ſcale between 62° and 68°, this laſt being the heat in which the lengths of the glaſs rods were laid off = 20.3352 inches, as deduced from the experiments with the pyrometer	1.6946
Hence we have the correct length of the baſe in the temperature of 62° reduced to the level of the lowermoſt extremity near Hampton Poor-houſe;	27404.7925
This laſt length requires yet a ſmall reduction for the height of this lowermoſt end above the mean level of the ſea, ſuppoſed to be fifty-four feet, or nine fathoms, . . .	0.0706
Hence the true or ultimate length of the baſe, reduced to the level of the ſea, and making a portion of the mean circumference of the earth, becomes	27404.7219

As ſome ſmall degree of uncertainty remains with regard to this laſt reduction, it may not be improper to ſay yet a few words on the principles that have been adhered to in making the computation. It will be remembered, that the meaſurement was made 3½ feet above the ſurface of the heath, that being the height of the ſtands whereon the rods were placed;

and that the teleſcopic ſpirit level gave a deſcent of 36.1 feet from the lowermoſt pipe to the ſurface of ſummer water in the Thames at Hampton. The accurate ſection of the river lately publiſhed, gives a fall of 13.33 feet from Hampton to the level of low water ſpring tides at Iſleworth. Now theſe three being added together, we have nearly fifty-three feet for the height of the baſe above Iſleworth. Having had no immediate means of determining what real difference there may be between Iſleworth and low water ſpring tides at the mouth of the Thames (for inſtance at the Hope or the Nore), I have ſuppoſed that fall to be about ſeven feet, ſo as to make the total deſcent ſixty feet. Now, ſuppoſing the ſpring tides at the Nore to riſe eighteen feet, if, according to M. de la Lande's method, we deduct one third of eighteen, *viz.* ſix feet from ſixty, we ſhall have fifty-four feet, or nine fathoms, that the mean ſurface of the ſea is below the meaſured baſe. Whether this concluſion be perfectly accurate or not is of no moment, ſince a whole fathom of difference (and I apprehend we are not farther from the truth) does not vary the reduction quite one-tenth of an inch. The reduced baſe has therefore been found by the following analogy: as the mean ſemi-diameter of the earth (ſuppoſed here to be 3492915 fathoms) augmented by nine fathoms, is to the mean ſemi-diameter, ſo is the meaſured baſe 27404.7925 to the reduced baſe 27404.7219 at the level of the ſea. It will doubtleſs be allowed, that infinite pains have been taken in the field and otherwiſe, throughout the whole of this operation, to obtain a juſt concluſion; but as the moſt accurate meaſurement imaginable is ſtill more liable to err in exceſs than in defect, we will throw away ſome uſeleſs decimals, and eſtabliſh the ultimate length of the baſe at 27404 feet and ſeven-tenths.

General Table of the Baſe, ſhewing the relative heights of the Stations above the ſouth-ea
Poor-houſe, the Reduction of the Hypothenuſes, and the Correction for the Tempera
whence the true length is obtained in the heat of 62°.

1	2	3	4	5	6	7	8	9	10	11	
Sections.	N° of hypothenuſes, 600 feet each.	Relative heights.				Reduction of the hypothenuſes.	Number of rods, twenty feet each.	Temperature.		Correction	
		Aſcent.	Deſcent.	Total aſcent.				Obſerved mean of 60 therm.	Exceſs or defect from 62°.	Expanſion above 62° + appt. leng.	Co be —
				Hypoth.	Sections.						
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.		°	°	Inches.	In
Firſt or ſouth-eaſt ſection, between Hampton Poor-houſe and Hanworth Summer-houſe.	1	0.07	– –	0.07		0.000012	29+ ·925521	71.4	+ 9.4	+0.2909	
	2	1.855	– –	1.925		0.002875	30	80.7	+18.7	+0.5801	
	3	– –	1.855	0.07		0.002875	30	80.6	+18.6	+0.5770	
	4	2.745	– –	2.815		0.006288	30	74.0	+12.0	+0.3722	
	5	2.92	– –	5.735		0 007114	30	62 6	+ 0.6	+0.0186	
	6	0.76	– –	6.495		0.000489	30	58.7	– 3.3		–
	7	1.57	– –	8.065		*0.000825	30	60.5	– 1.5		–
	8	2.91	– –	10.975		0.007065	30	63.3	+ 1.3	+0.0403	
	9	– –	0.68	10.295		0.000393	30	64.1	+ 2.1	+0.0651	
	10	0.65	– –	10.945		0.000360	30	66.6	+ 4.6	+0.1427	
	11	– –	0.04	10.905		0.000009	30	70.4	+ 8.4	+0.2606	
	12	– –	1.18	9.725		0.001168	30	69.9	+ 7.9	+0.2451	
	13	0.83	– –	10.555	10.555	0.000581	30	62.7	+ 0.7	+0.0217	
Second or middle ſection, between Hanworth Summer-houſe and the north ſide of the Staines Road.	14	– –	0.94	9.615		0.000745	30	60.7	– 1.3		–
	15	0.42	– –	10.035		0.000191	30	63.2	+ 1.2	+0.0372	
	16	– –	1.63	8.405		0.002222	30	69.0	+ 7.0	+0.2171	
	17	0.28	– –	8.685		0.000073	30	71.1	+ 9.1	+0.2823	
	18	4 16	– –	12.845		0.014439	30	68.6	+ 6.6	+0.2047	
	19	– –	0.44	12.405		0.000169	30	63.5	+ 1.5	+0.0465	
	20	0.19	– –	12.595		0.000036	30	59.2	– 2.8		–
	21	1.87	– –	14 465		0.002922	30	56.2	– 5.8		–
	22	0.73	– –	15.195		0.000452	30	57.0	– 5.0		–
	23	0.39	– –	15 585		0.000135	30	64.1	+ 2.1	+0.0651	
	24	0.95	– –	16.535		0.000760	30	64.3	+ 2.3	+0.0713	
	25	0.49	– –	17.025		0·000208	30	62.5	+ 0.5	+0.0155	
	26	2.11	– –	19.135	8.58	*0.000063	30	71.1	+ 9.1	+0.2823	
d or north-weſt ſection, between the north of the Staines Road, and King's Arbour near Colnbrook Road.	27	– –	0.71	18.425		*0.000214	30	70.5	+ 8.5	+0.2637	
	28	0.245	– –	18.67		0.000057	30	63.3	+ 1.3	+0.0403	
	29	1.21	– –	19.88		0.001228	30	59.2	– 2.8		–
	30	– –	0.165	19.715		0.000028	30	66.2	+ 4.2	+0.1303	
	31	0.14	– –	19.855		0.000024	30	73.8	+11.8	+0.3660	
	32	– –	0.12	19.735		0.000019	30	77.6	+15.6	+0.4839	
	33	– –	0.14	19.595		0.000024	30	73.7	+11.7	+0.3629	
	34	1.21	– –	20.805		0.001228	30	68.8	+ 6.8	+0.2109	
	35	1.405	– –	22.21		0.001653	30	65.8	+ 3.8	+0.1179	
	36	2.34	– –	24.55		0.004571	30	65.5	+ 3.5	+0.1086	
	37	– –	1.085	23.465		0.000985	30	61.5	– 0.5		–
	38	0.47	– –	23.935		0.000192	30	59.4	– 2.6		–
	39	0.525	– –	24.46		0.000238	30	55.6	– 6.4		–
	40	1.265	– –	25.725		0.001341	30	55.1	– 6.9		–
	41	1.18	– –	26.905		0.001168	30	56.1	– 5.9		–
	42	– –	0.19	26.715		0.000036	30	58.4	– 3.6		–
	43	1.565	– –	28.28		0.002049	30	58.2	– 3.8		–
	44	1.485	– –	29.765		0.001845	30	57.3	– 4.7		–
	45	0.24	– –	30.005		0.000055	30	60.8	– 1.2		–

uth-eaſt extremity near Hampton
emperature of the Glaſs Rods;

11	12	13	14
rrection for temperature.			Correct length of the baſe.
nſion e 62° pt. leng.	Contract. below 62° — appt. leng.	Difference.	
es.	Inches.	Inches.	Feet.
2909			
5801			
5770			
3722			
0186			
	−0.1024		
	−0.0465		
0403			
0651			
1427			
.2606			
2451			
0217			
	−0.0403		
.0372			
.2171			
2823			
.2047			
0465			
	−0.0869		
	−0.1799		
	−0.1551		
0651			
0713			
.0155			
.2823			
.2637			
.0403			
	−0.0869		
.1303			
.3660			
.4839			
.3629			
.2109			
.1179			
.1086			
	−0.0155		
	−0.0807		
	−0.1985		
	−0.2140		
	−0.1830		
	−0.1117		
	−0.1179		
	−0.1458		
	−0.0272		

Third or no ſide of the S the Colnbro	42	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	— [illegible]		—
	43	1.565	– –	28.28		0.002049	30	58.2	— 3.8		—
	44	1.485	– –	29.765		0.001845	30	57.3	— 4.7		—
	45	0.24	– –	30.005		0.000055	30	60.8	— 1.2		—
	46	1.26	– –	31.265	12.130	0.001973	20	65.3	+ 3.3	+0.0682	
	400 ft.										
		40.44	9.175	31.265	31.265	0.071401	1369+ .925521			+5.9890	—

Hypothenuſal length of the baſe containing 1369.925521 glaſs rods of twenty feet each +4.31 feet, -
Reduction contained in the ſeventh column to be ſubtracted, - - - -

Total apparent length of the baſe reduced to the level of the ſouth-eaſt extremity, - -
Add to the apparent length the difference between the expanſion of glaſs above, and the contraction of
contained in the thirteenth column = 4.1867 inches = - - - - -
Add further to the apparent length the equation for 6° difference of temperature of the ſtandard braſs ſcale bet
68°, the heat in which the glaſs rods were laid off = 20.3352 inches, = - - - -

Correct length of the baſe in the temperature of 62°, reduced to the level of the lowermoſt extremity, -
Reduction for the height of the lower end of the baſe above the mean level of the ſea, ſuppoſed to be 54 feet

True length of the baſe reduced to the mean level of the ſea, - - - -

.0682	−0.1117 −0.1179 −0.1458 −0.0372	
.9890	−1.8023	+4.1867

- -	=	27402.8204
- -	−	0.0714
- -		27402.7490
tion of it below 62°, - - -	+	0.3489
ſcale between 62° and - -	+	1.6946
- -	=	27404.7925
54 feet or 9 fathoms =	−	0.0706
- -	=	27404.7219

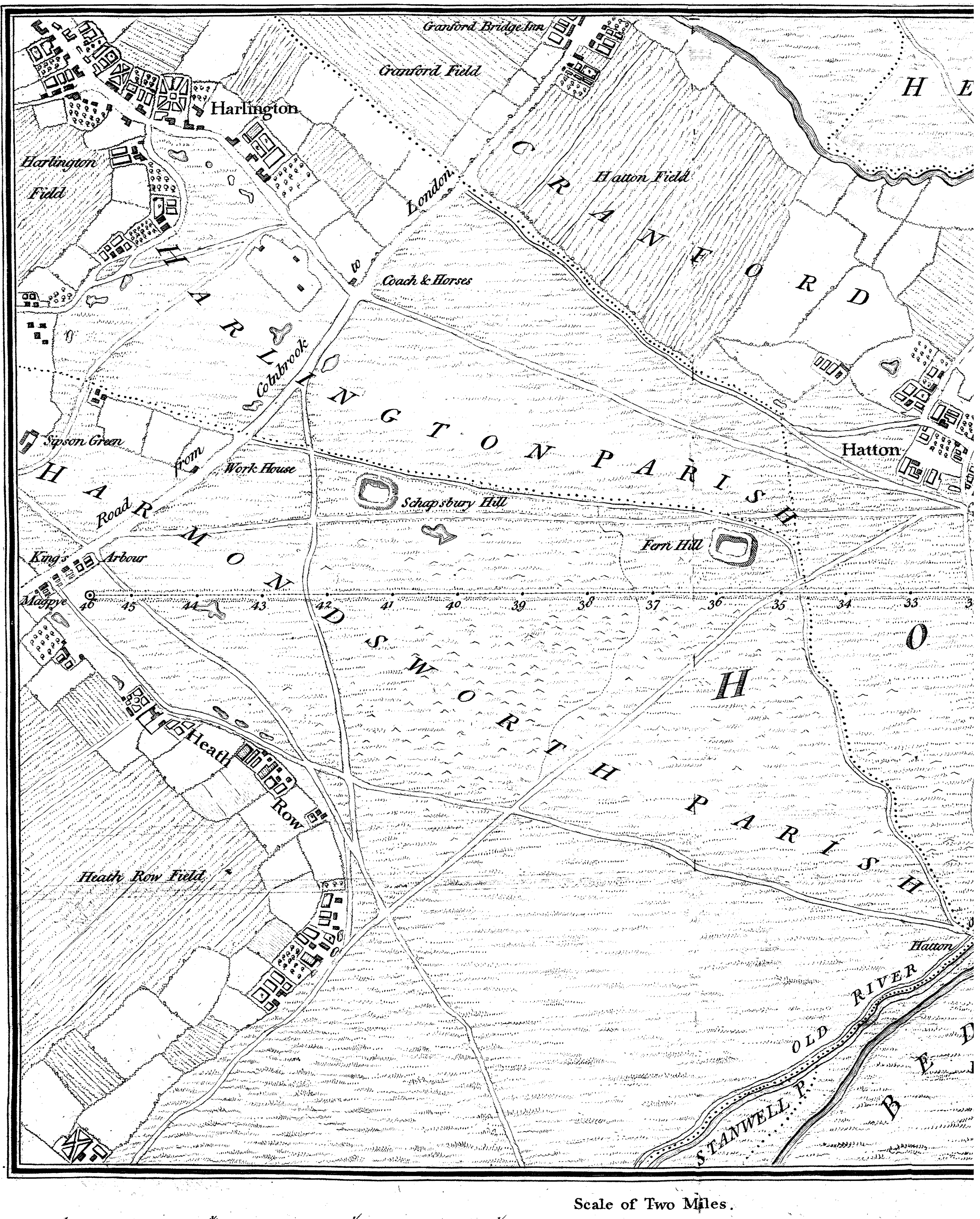
Table

Table of the Expanſions of Metals, deduced from experiment

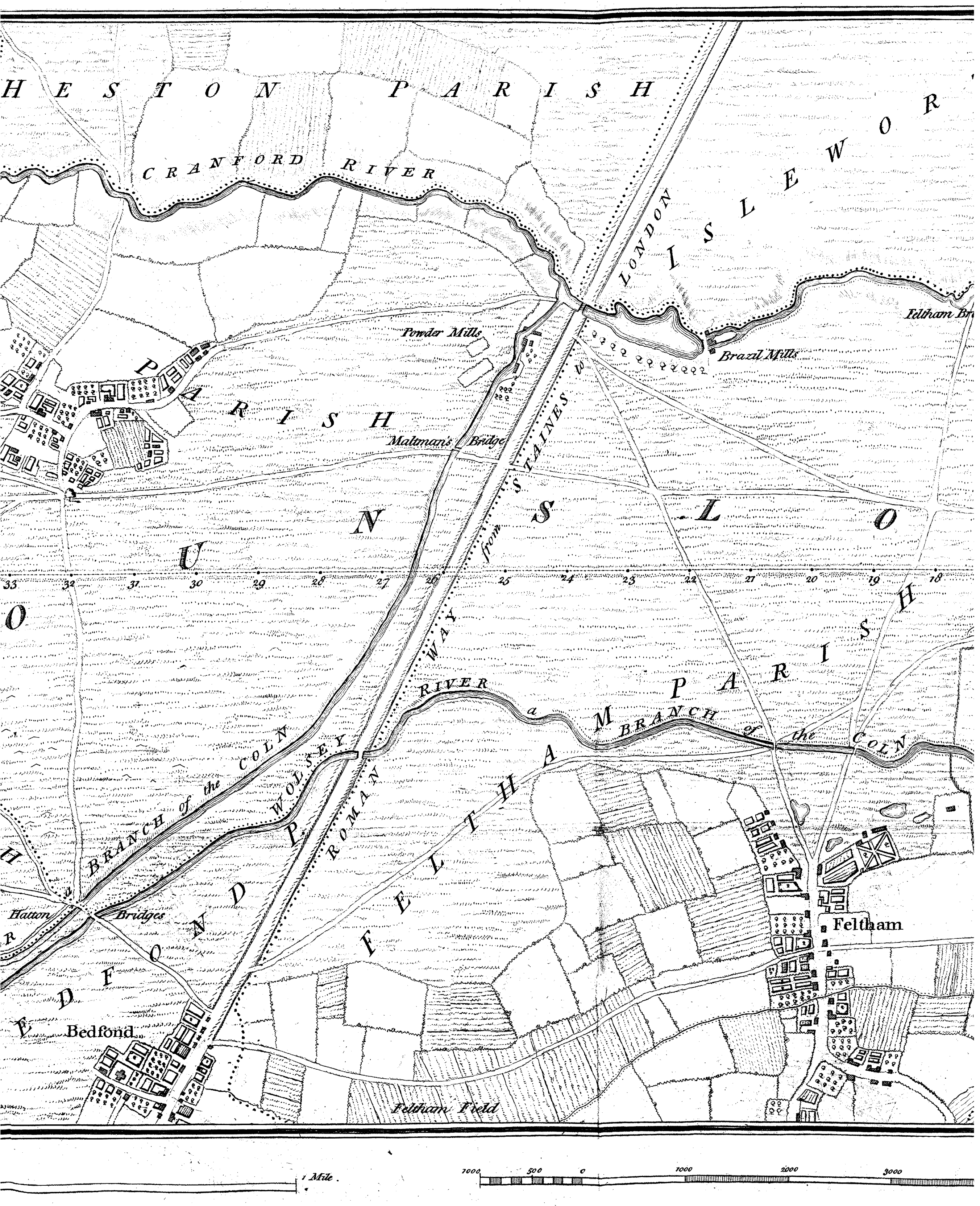
Deſcription of the Metal Rods put to experiment.		Revolutions and parts of the micrometer for the expanſion on five feet.		Actual expanſion in parts of inch by 180°, the revolutic being divided by 32.06.		
		By 180°	By 1°.	On 5 feet.	On 1 foot.	On 100
		Rev.Pts.	Parts.	In.	In.	In.
Standard braſs ſcale.	Suppoſed to be Hamburgh plate braſs; length 42.187 inches, or 3.568 feet; breadth 0.55 inch; thickneſs 0.25 inch; and weight 1 lb. 10½ oz. Its expanſion was meaſured by 25.47 revolutions of the micrometer; wherefore that on five feet would have been meaſured by -	35.69	19.$\frac{83}{100}$	0.111323	0.0222646	2.2264
Engliſh plate braſs, in form of a rod.	Length five feet; breadth 0.9 inch; thickneſs 0.15 inch; and weight 2 lbs. 5½ oz. Difficult from its thinneſs to be kept free from warping, - - -	36.41	20.$\frac{23}{100}$	0.113568	0.0227136	2.2713
Engliſh plate braſs, in form of a trough.	Length five feet; breadth 1.4 inch; depth 1 inch; weight 8 lbs. 3 oz. Perfectly ſtrong and ſtraight, - - -	36.45	20.$\frac{25}{100}$	0.113693	0.0227386	2.2738
Steel rod.	Length five feet; breadth 0.5 inch; thickneſs 0.3 inch; weight 2 lbs. 7½ oz. Made from the very ſame bar with the chain, - -	22.02	12.$\frac{23}{100}$	0.068684	0.0137368	1.3736
Caſt iron priſm.	Length five feet; each of its ſides 1¼ inch; and weight 11 lbs. 9 oz Cut from the ſame rod with the ſtandard priſms of the pyrometer,	21.34	11.$\frac{86}{100}$	0.066563	0.0133126	1.3312
Glaſs tube.	Length five feet; $\frac{93}{100}$ths inch diameter; weight 1 lb. 13½ oz. Drawn from the ſame pot of metal with the meaſuring rods, - -	14.93	8.$\frac{29}{100}$	0.046569	0.0093138	0.9313
Solid glaſs rod.	Length 40.44 inches, or 3.37 feet; mean diameter ſix-tenths of an inch; and weight 1 lb. 2 oz. It had been applied for ſeveral years to a clock. Its expanſion was meaſured by 10.46 revolutions of the micrometer; wherefore that on five feet would have been meaſured by -	15.54	8.$\frac{63}{100}$	0.048472	0.0096944	0.9694

eriments made with the Microſcopic Pyrometer in April 1785.

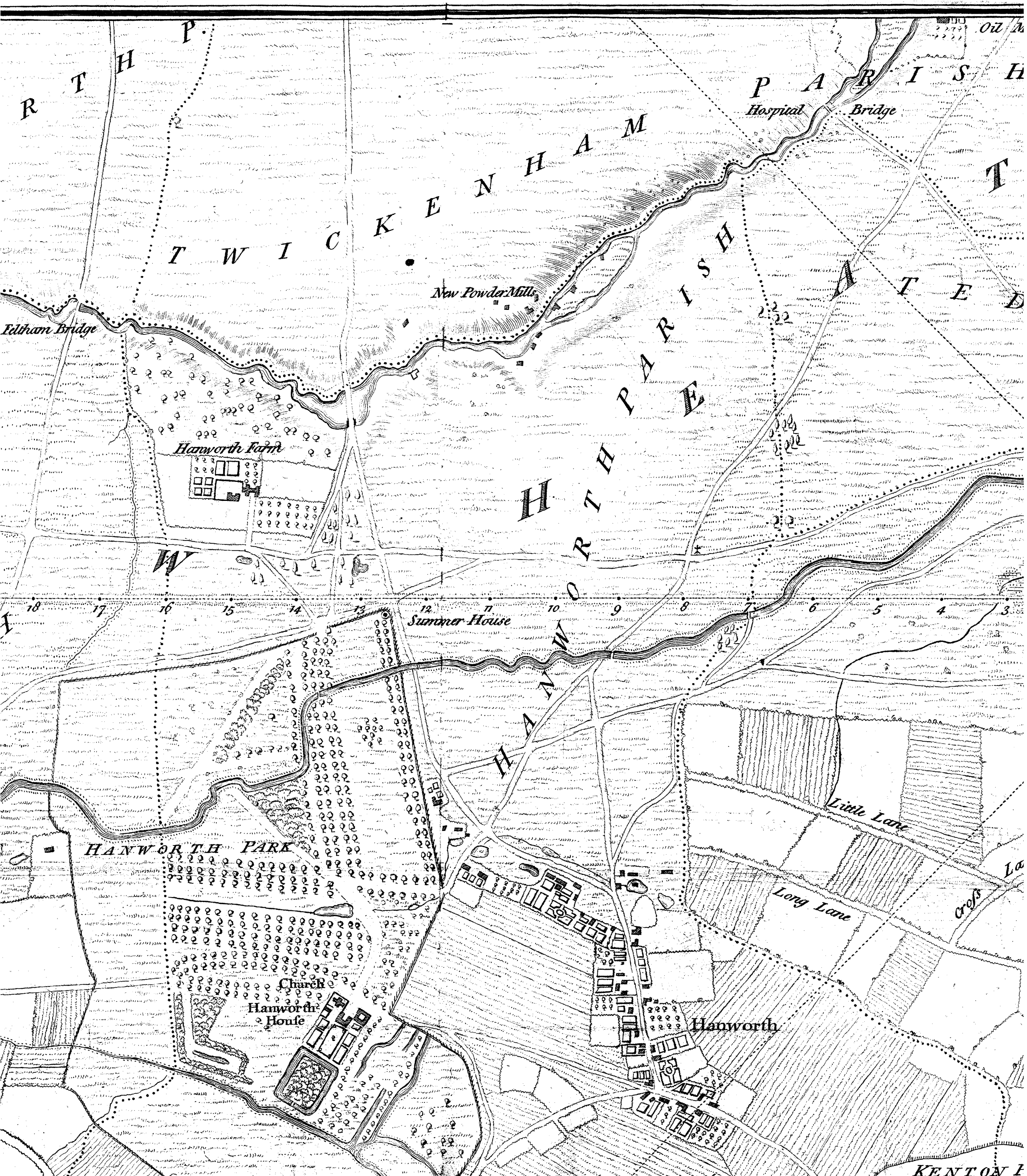
parts of an revolutions 6.	By 1° of Fahrenheit the expanſion is						Baſes of 27400 feet of theſe meta would expand.			
On 100 ft.	On 1 foot.	10 feet.	100 feet.	400 feet.	600 feet.	1000 ft.	By 1°.	By 10°.	By 20°.	By 30°.
In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
2.22646	0.0001237	0.001237	0.01237	0.04948	0.07422	0.1237	3.38938	33.8938	67.7876	101.6814
2.27136	0.0001262	0.001262	0.01262	0.05048	0.07572	0.1262	3.45788	34.5788	69.1576	103.7364
2.27386	0.0001263	0.001263	0.01263	0.05052	0.07578	0.1263	3.46062	34.6062	69 2124	103.8168
1.37368	0.0000763	0.000763	0.00763	0.03052	0.04578	0.0763	2.09062	20.9062	41.8124	62.7186
1.33126	0.0000740	0.000740	0.00740	0.02960	0.04440	0.0740	2.02760	20.2760	40.5520	60.8280
0.93138	0.0000517	0.000517	0.00517	0.02068	0.03102	0.0517	1.41658	14.1658	28.3316	42.4974
0.96944	0.0000539	0.000539	0.00539	0.02156	0.03234	0.0539	1.47686	14.7686	29.5372	44.3058

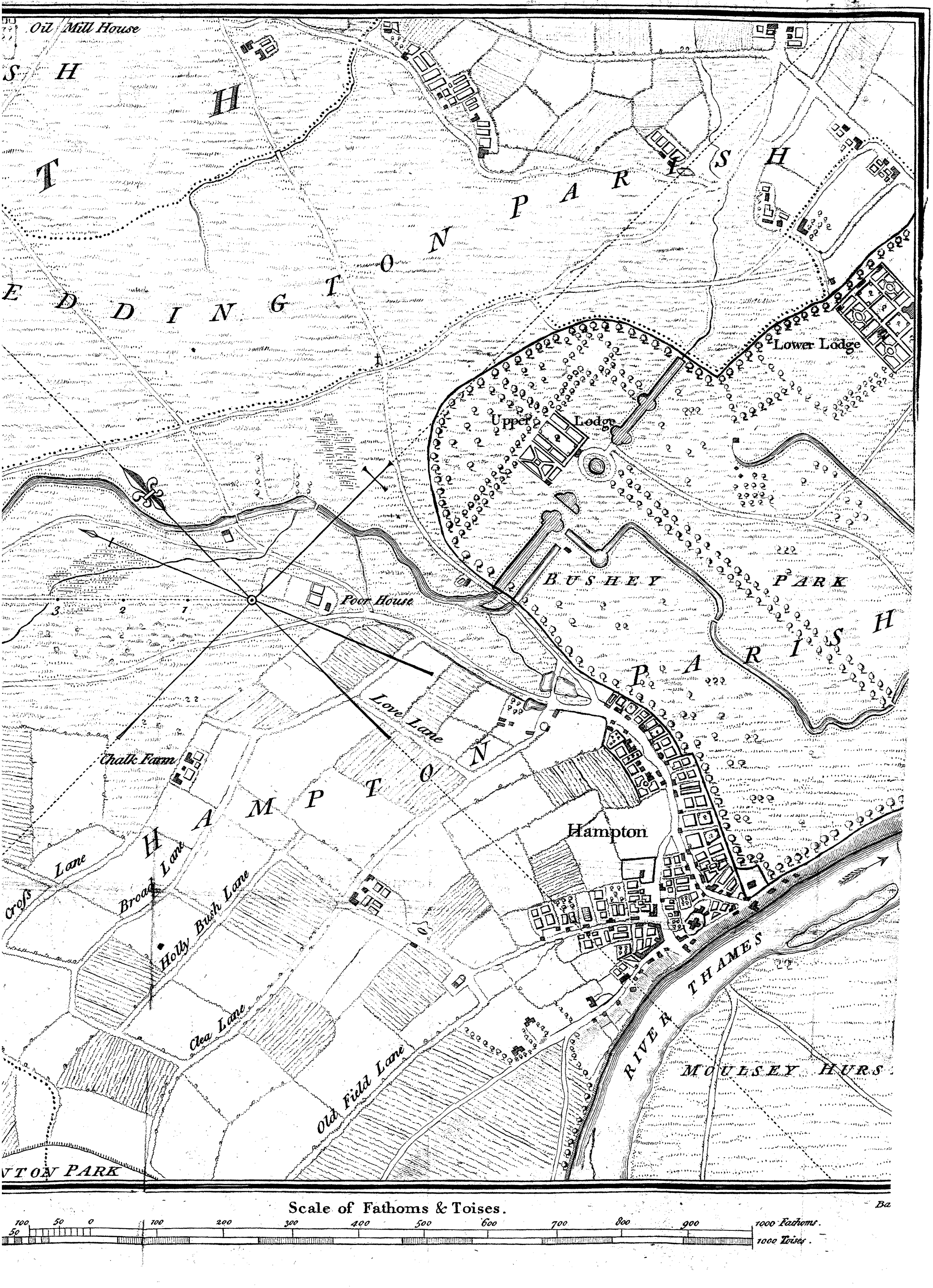

Granford Bridge Inn
Granford Field
Harlington
Harlington Field
to London
Coach & Horses
HARLINGTON PARISH
CRANFORD
Hatton Field
HE
Colnbrook
Sipson Green
from
Work House
Road
Schapsbury Hill
Fern Hill
Hatton
King's Arbour
Magpye
HARMONDSWORTH PARISH
46
45
44
43
42
41
40
39
38
37
36
35
34
33
O
H
Heath Row
Heath Row Field
Hatton
OLD RIVER
STANWELL P.
B E D
Scale of Two Miles.
1
3/4
1/2
1/4
0

PLAN ſhewing the ſituation of the BASE meaſured

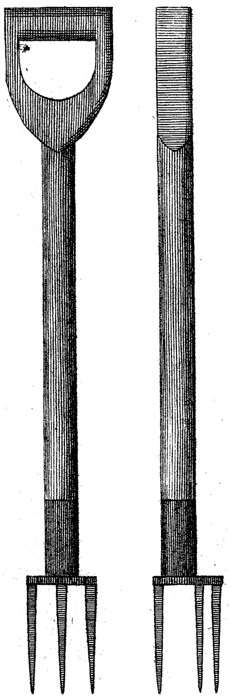


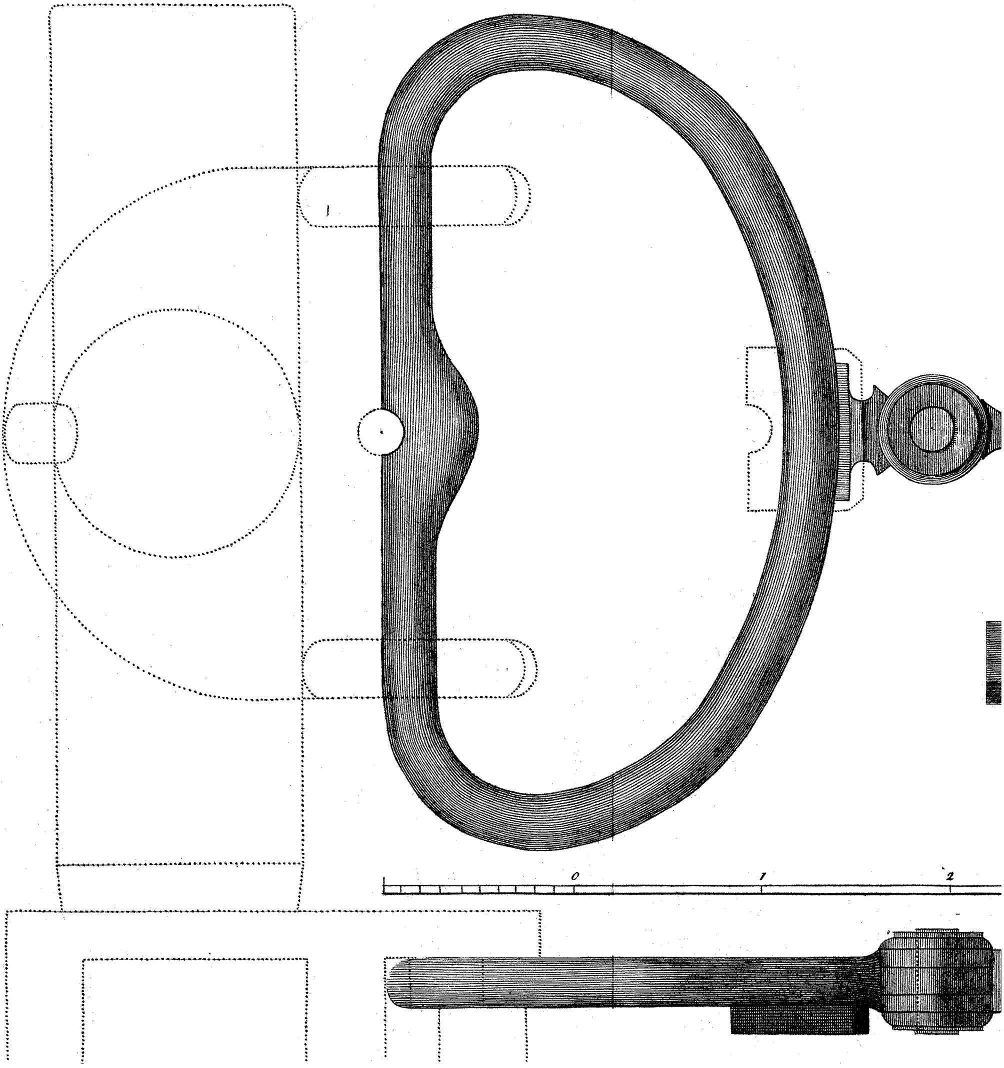
ured on HOUNSLOW HEATH in Summer 1784.



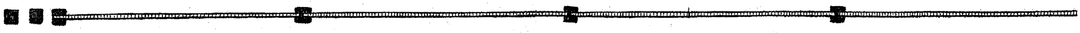

Oil Mill House
S H
H
T
E D D I N G T O N
P A R I S H
Lower Lodge
Upper Lodge
B U S H E Y
P A R K
P A R I S H
Poor House
3
2
1
Love Lane
Chalk Farm
H A M P T O N
Hampton
Cross Lane
Broad Lane
Holly Bush Lane
Clea Lane
Old Field Lane
RIVER THAMES
MOULSEY HURS
TON PARK
Scale of Fathoms & Toises.
100
50
0
50
100
200
300
400
500
600
700
800
900
1000 Fathoms.
1000 Toises.
Ba

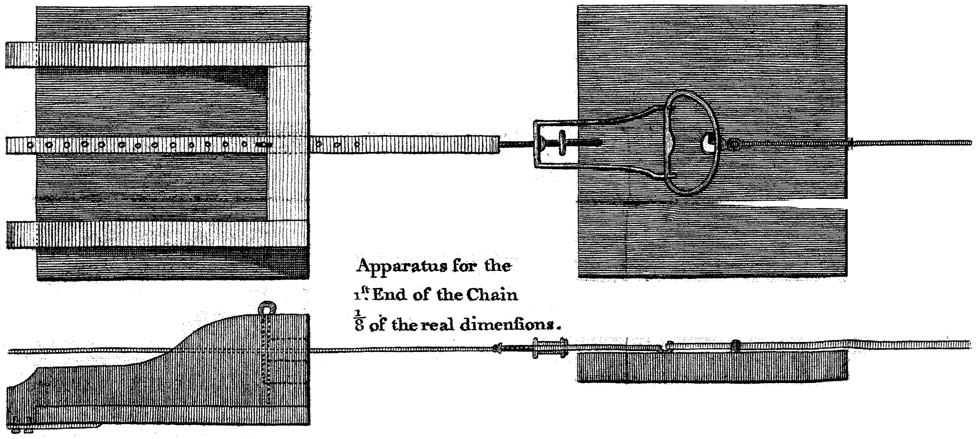
Holdfaſt for the 1st End of the Chain.





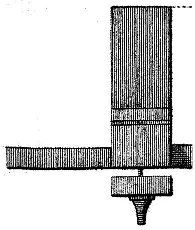
Diſpoſition





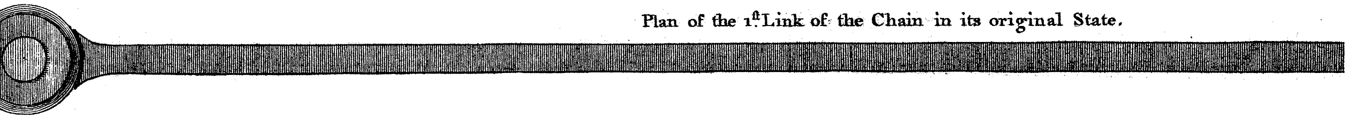
Apparatus for the 1st End of the Chain $\frac{1}{8}$ of the real dimenſions.

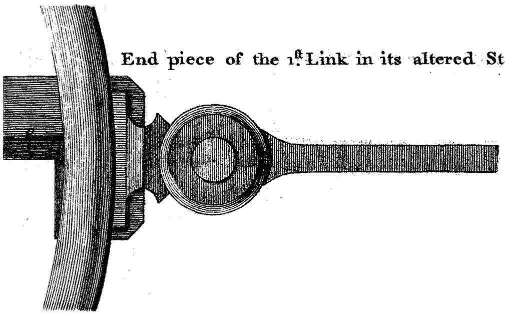
Side Elevation of the



For the DESCRIPTION and APPLICATION of the

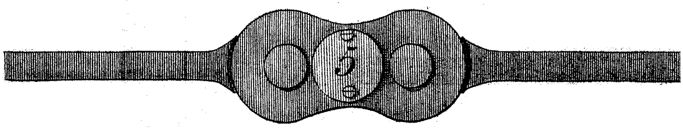
Plan of the 1st Link of the Chain in its original State.

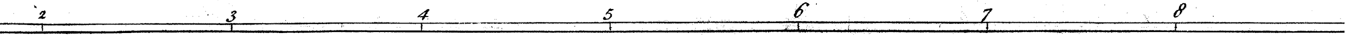




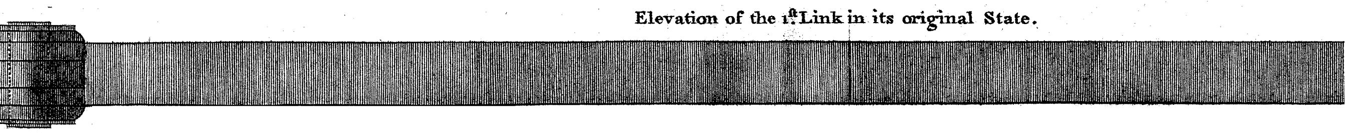
End piece of the 1st Link in its altered State.

Plan of the Croſs joint at every 10th Link.

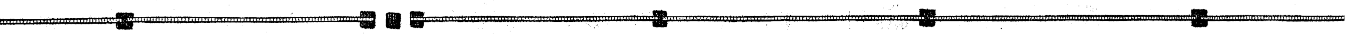




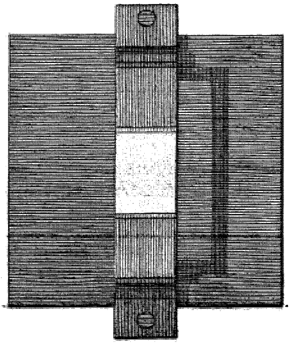
Elevation of the 1st Link in its original State.

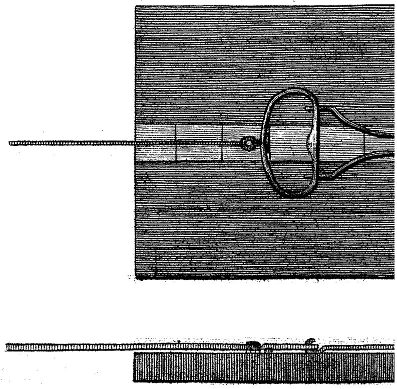


iſpoſition of Seventeen Stands for the double Meaſurement with the Chain and Glaſs Rods.

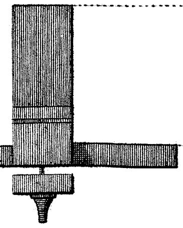


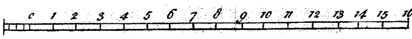
Top of the Card Stand.



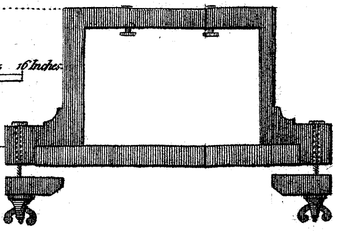


tion of the Card Stand.

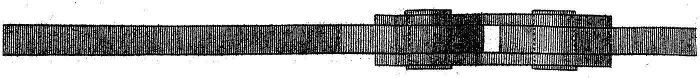


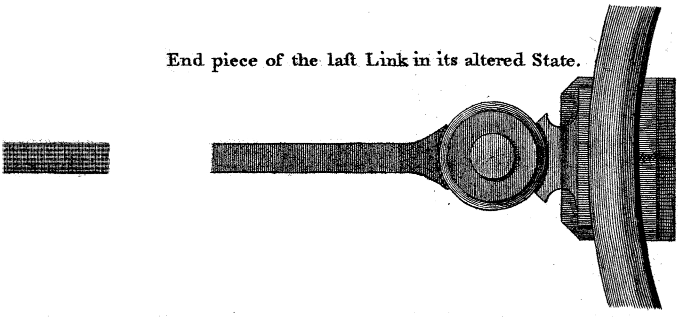


End Elevation of the Card Stand.

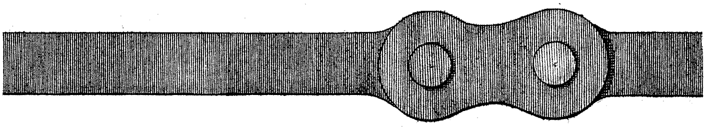


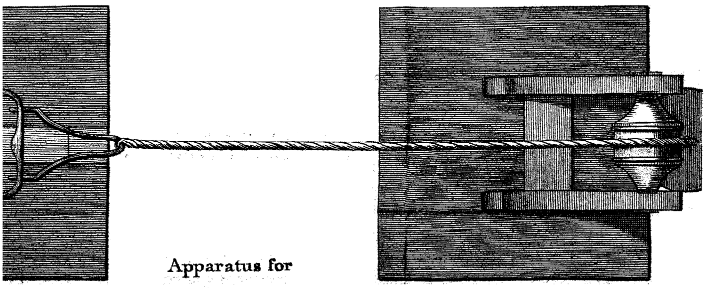
f the STEEL CHAIN.



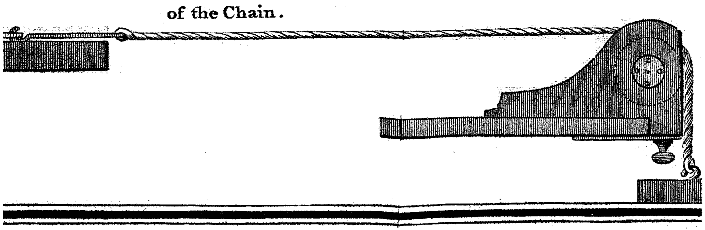


End piece of the last Link in its altered State.





Apparatus for
the last End
of the Chain.



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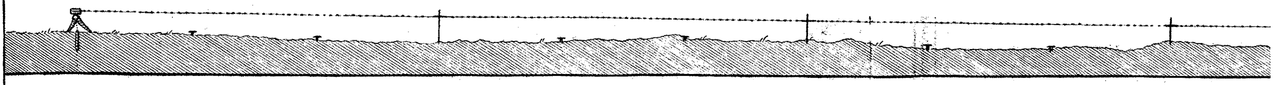
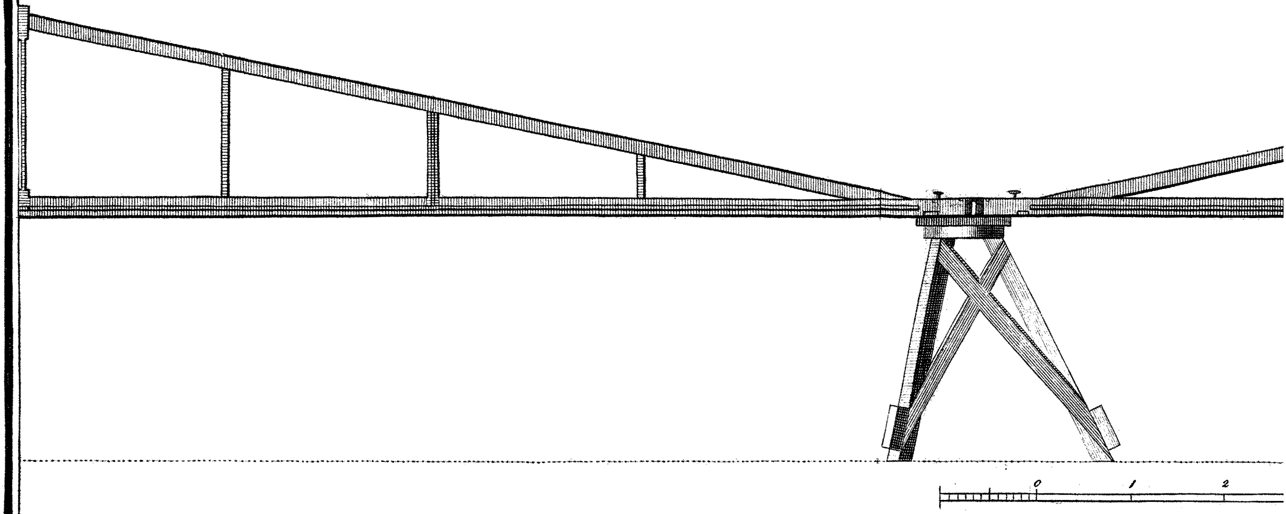
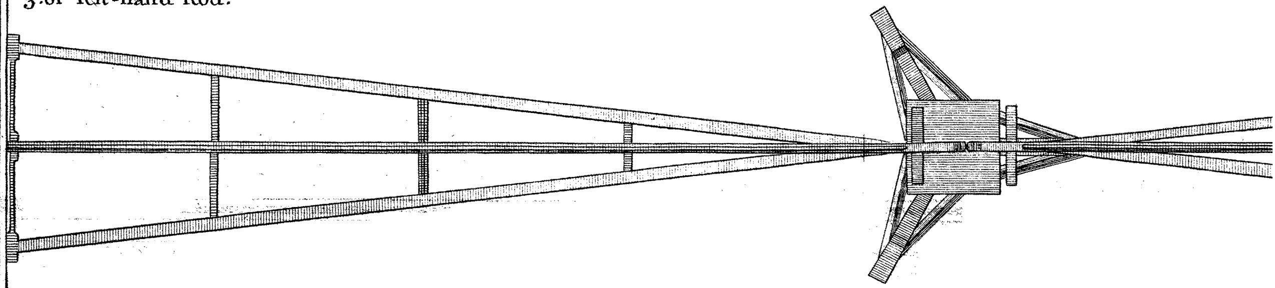


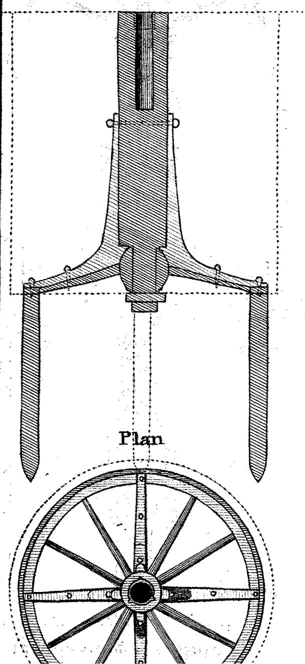
Subdivision o



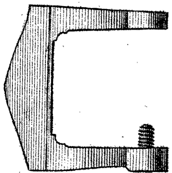
3d or left-hand Rod.



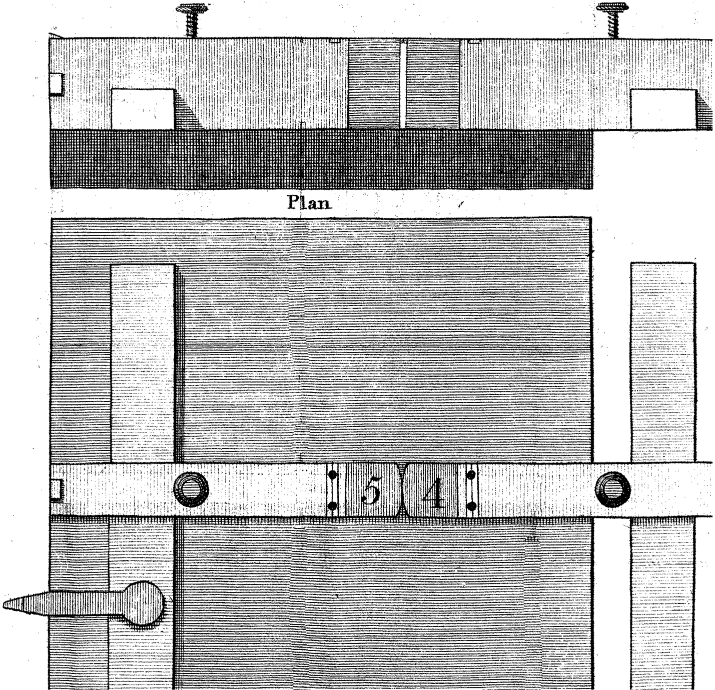
Section of the Pipe & Wheel terminating the Base.



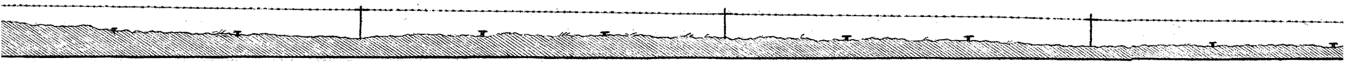
Vertical Clamp.



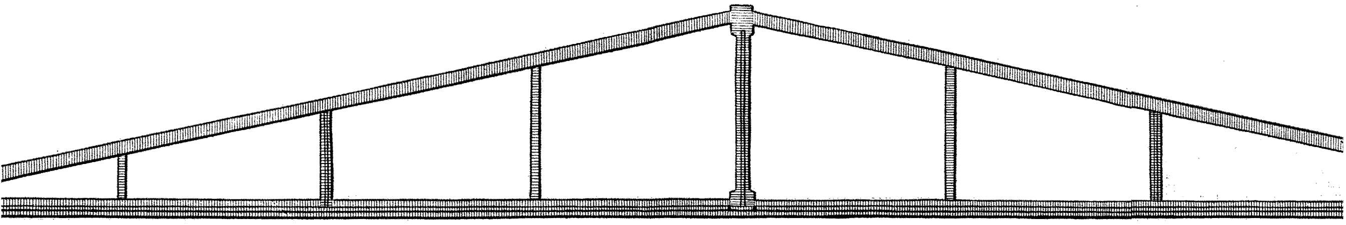
Elevation of the Ends of the Rods in Contact $\frac{1}{4}$ of the real dimen

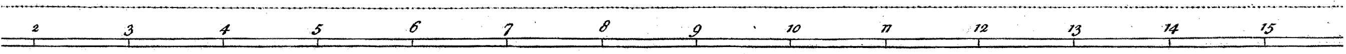


For the DESCRIPTION and APPLICATION of the DEAL RODS &c.

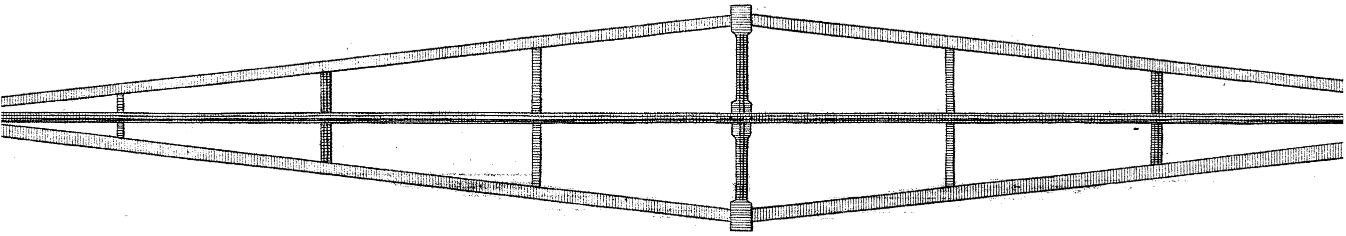


diviſion of the Ground of one Hypothenuſe of 600 Feet into 30 Rod Lengths, and method of tracing the Line through the

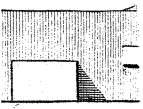




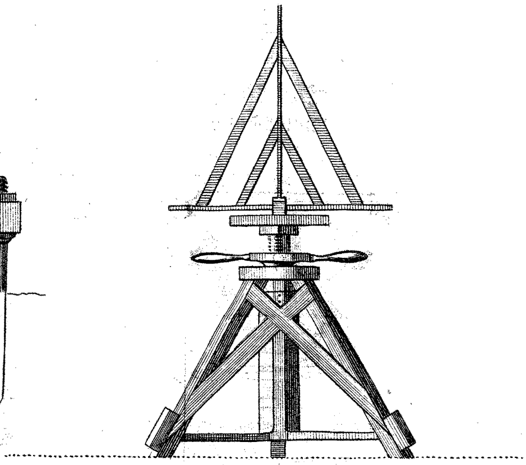
2^d or middle Rod.



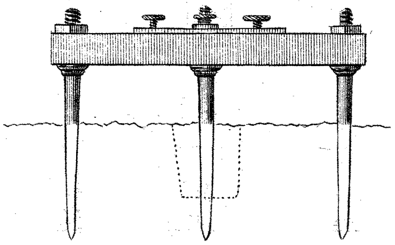
al dimenſions.

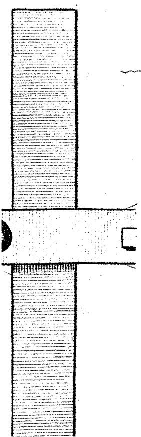


Elevation the Rods seen endwiſe.

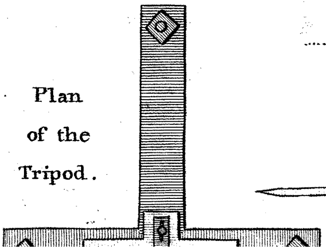


Elevation of the Tripod.

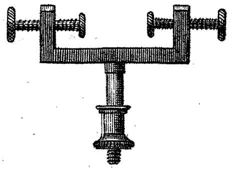




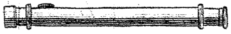
Plan of the Tripod.



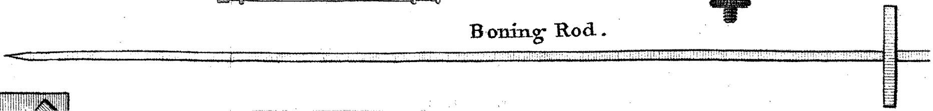
Horizontal Clamp.



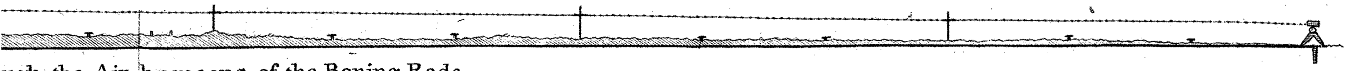
Boning Teleſcope.



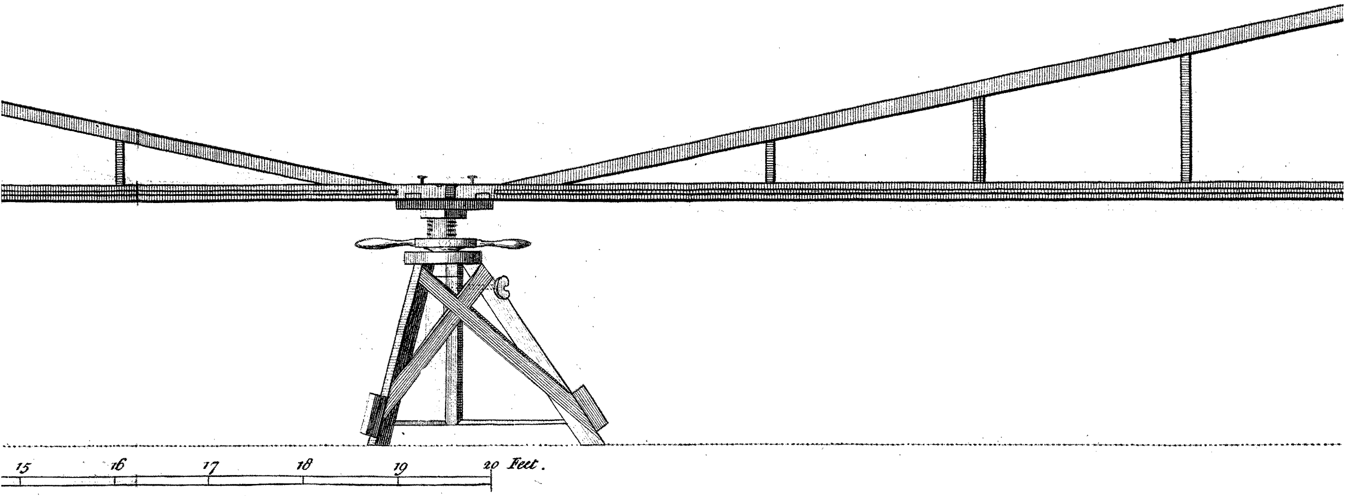
Boning Rod.

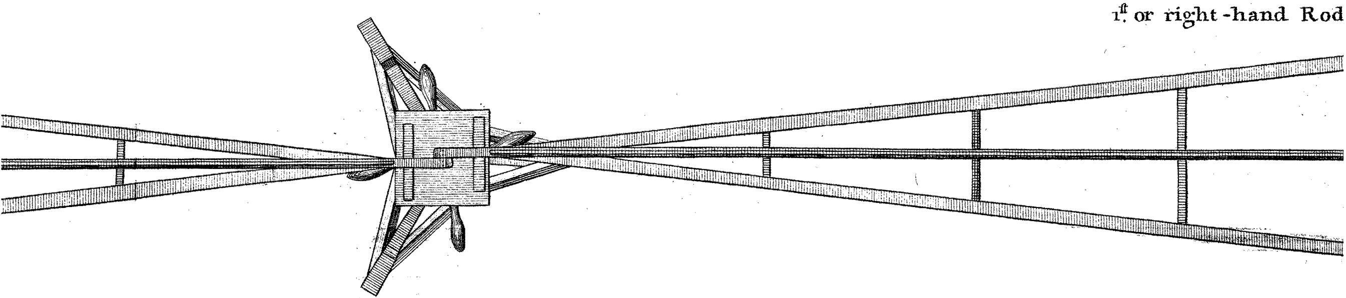


c.

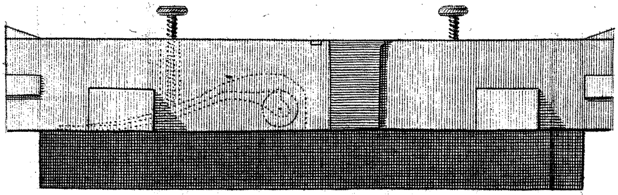


ugh the Air by means of the Boning Rods.

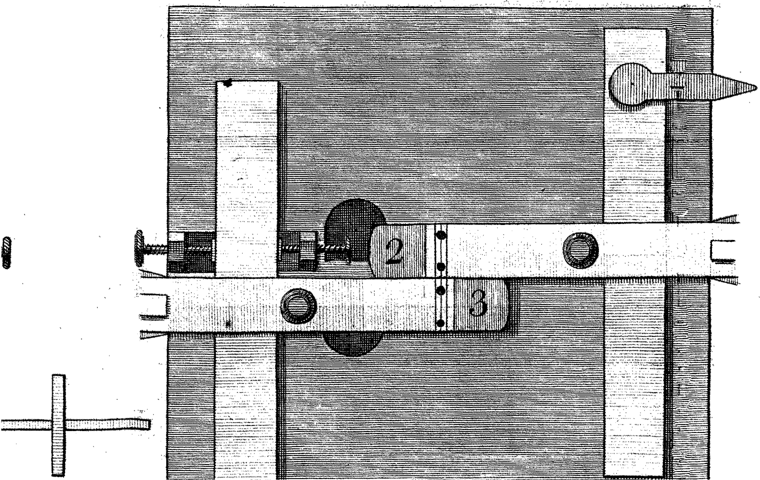




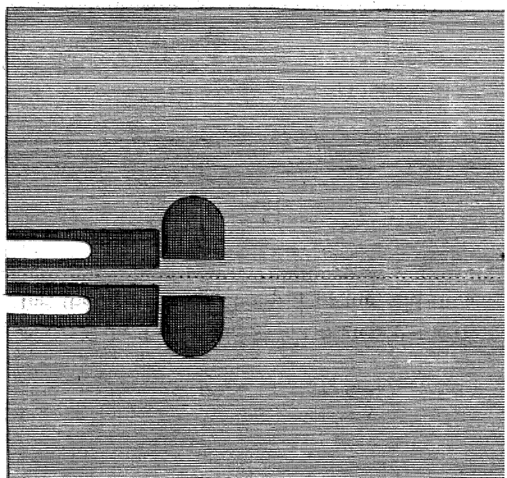
Elevation of the Ends of the Rods in Coincidence.

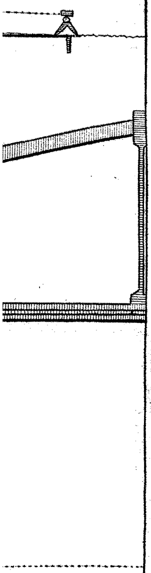


Plan

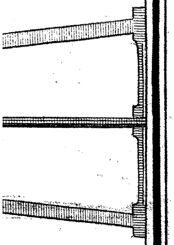


Plan of the Top of the Stand ſhewing the Groo
for the horizontal Clamp $\frac{1}{4}$ of the real dimenſ

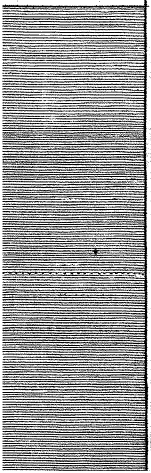


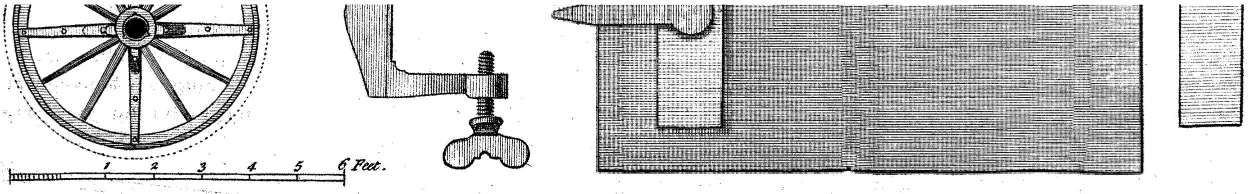


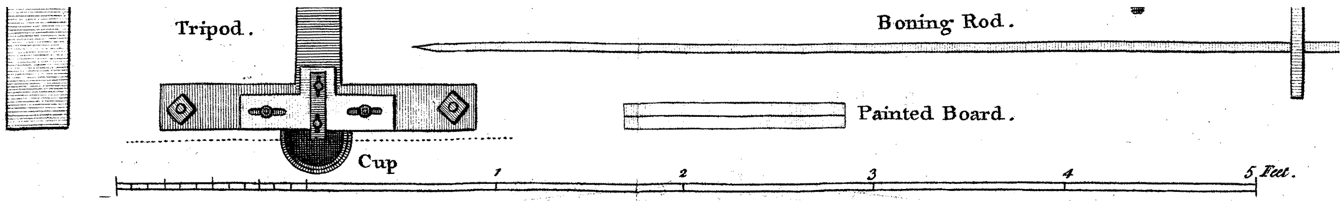
and Rod.

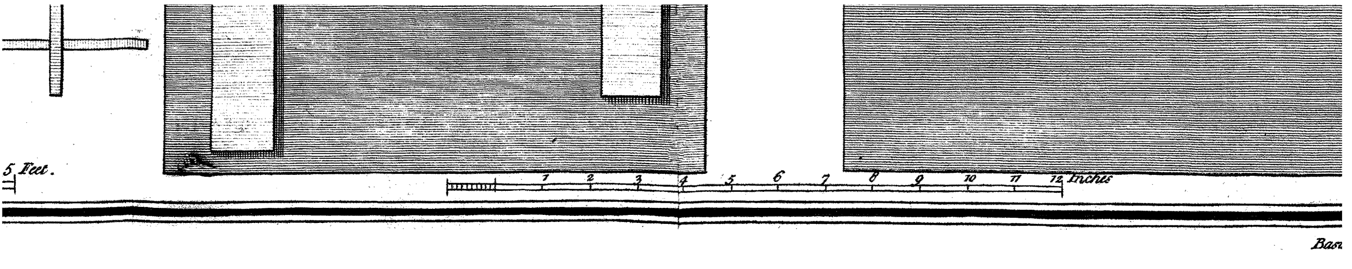


the Grooves
l dimenſions.

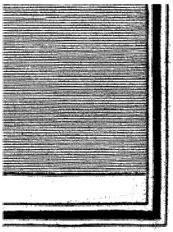



6 Feet.

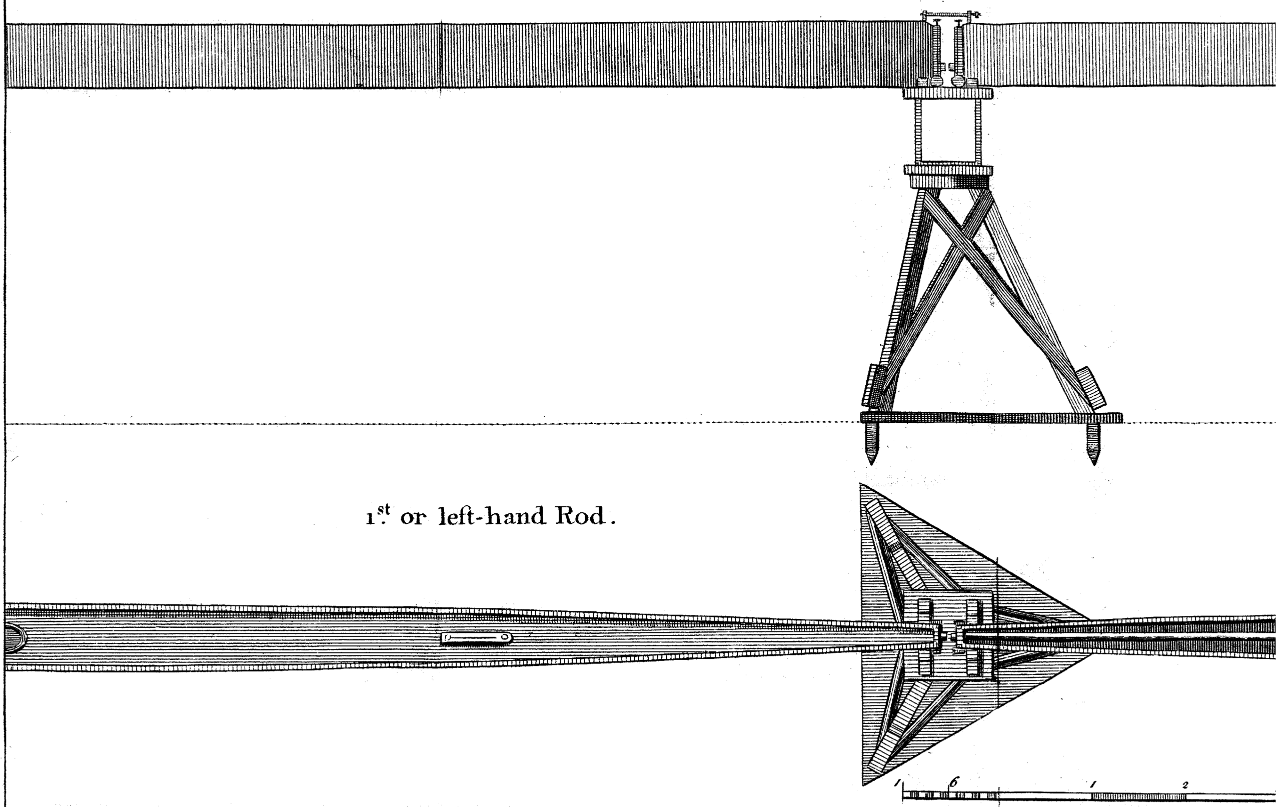

Tripod.
Boning Rod.
Painted Board.
Cup
1
2
3
4
5 Feet.



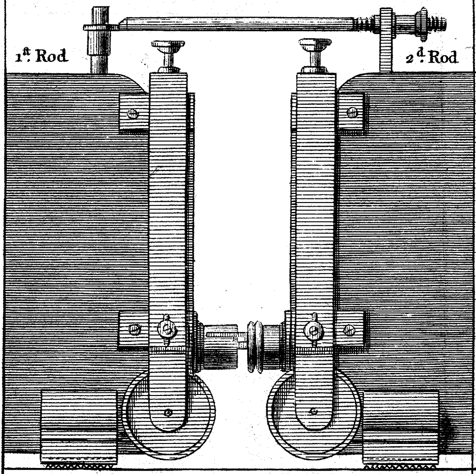
Basi



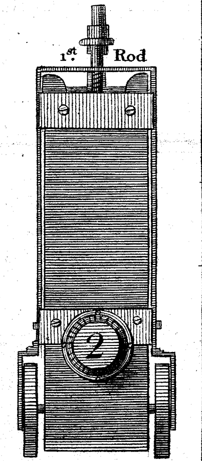
Basire sc.



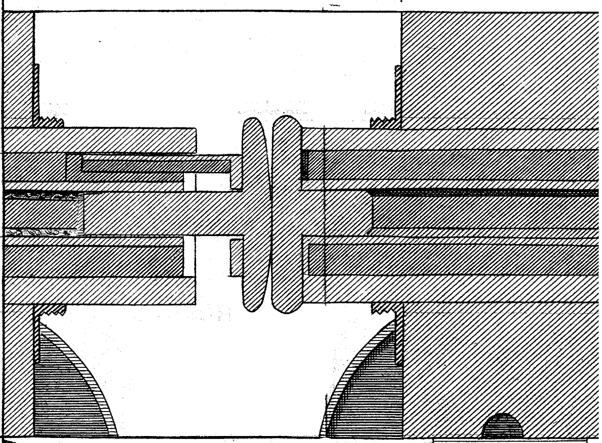
Longitudinal Elevation $\frac{1}{4}$ of the real dimenſions.



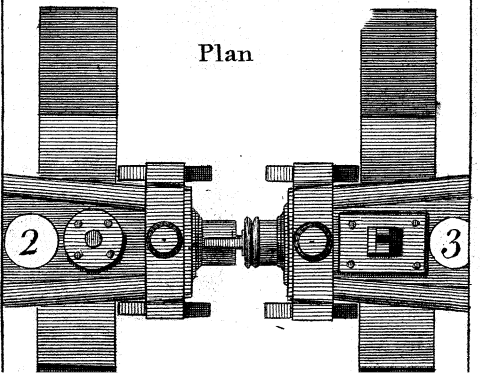
Front Elevation of the moveable End.



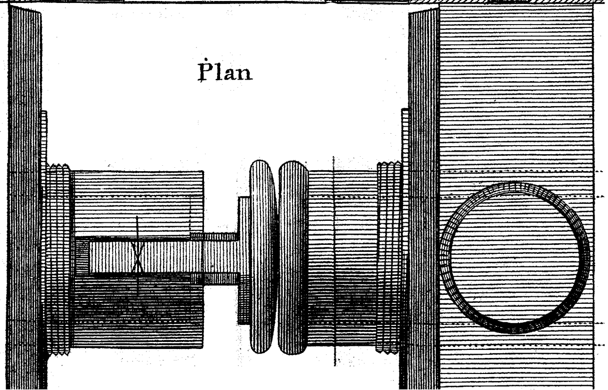
Longitudinal Section of the moveable End of the 1st
2d Rod in their real dimenſions.



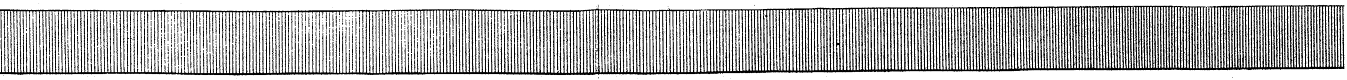
Plan



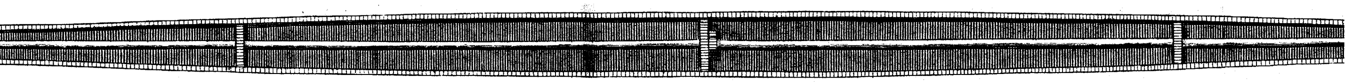
Plan



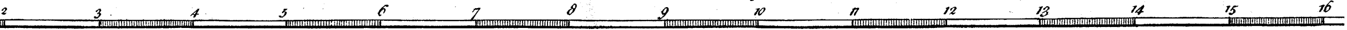
For the DESCRIPTION and APPLICATION of the GLASS RODS.



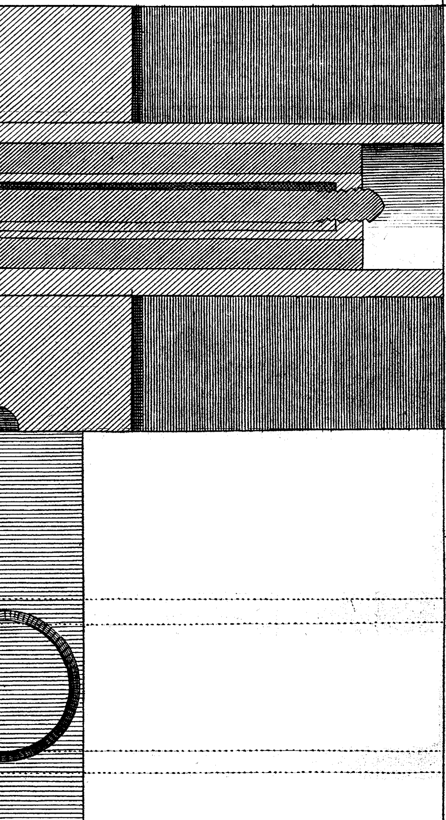
2d. or middle Rod.



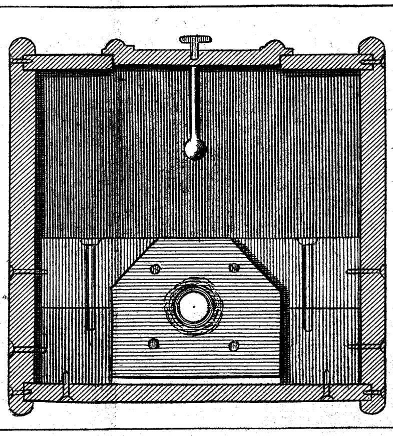
Scale of Feet.

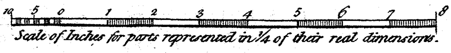


of the 1st Rod and fixed End of the

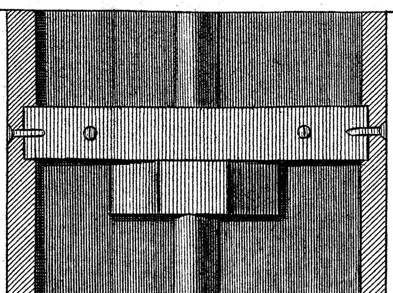


Section acroſs the middle of the Rod $\frac{1}{4}$ of the real dimenſions.

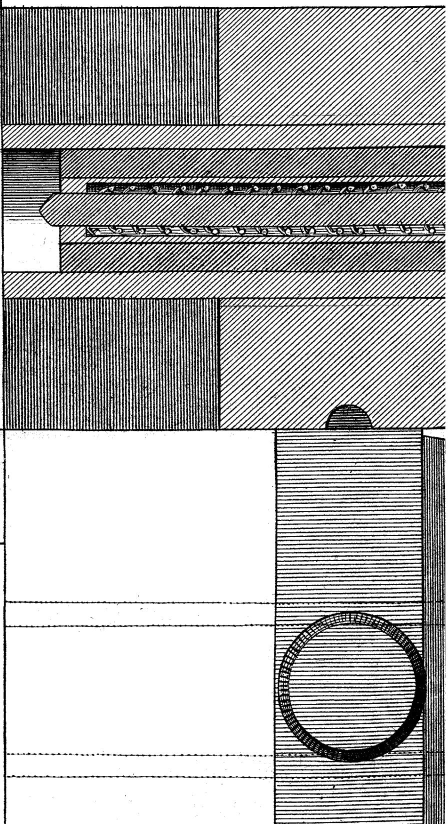


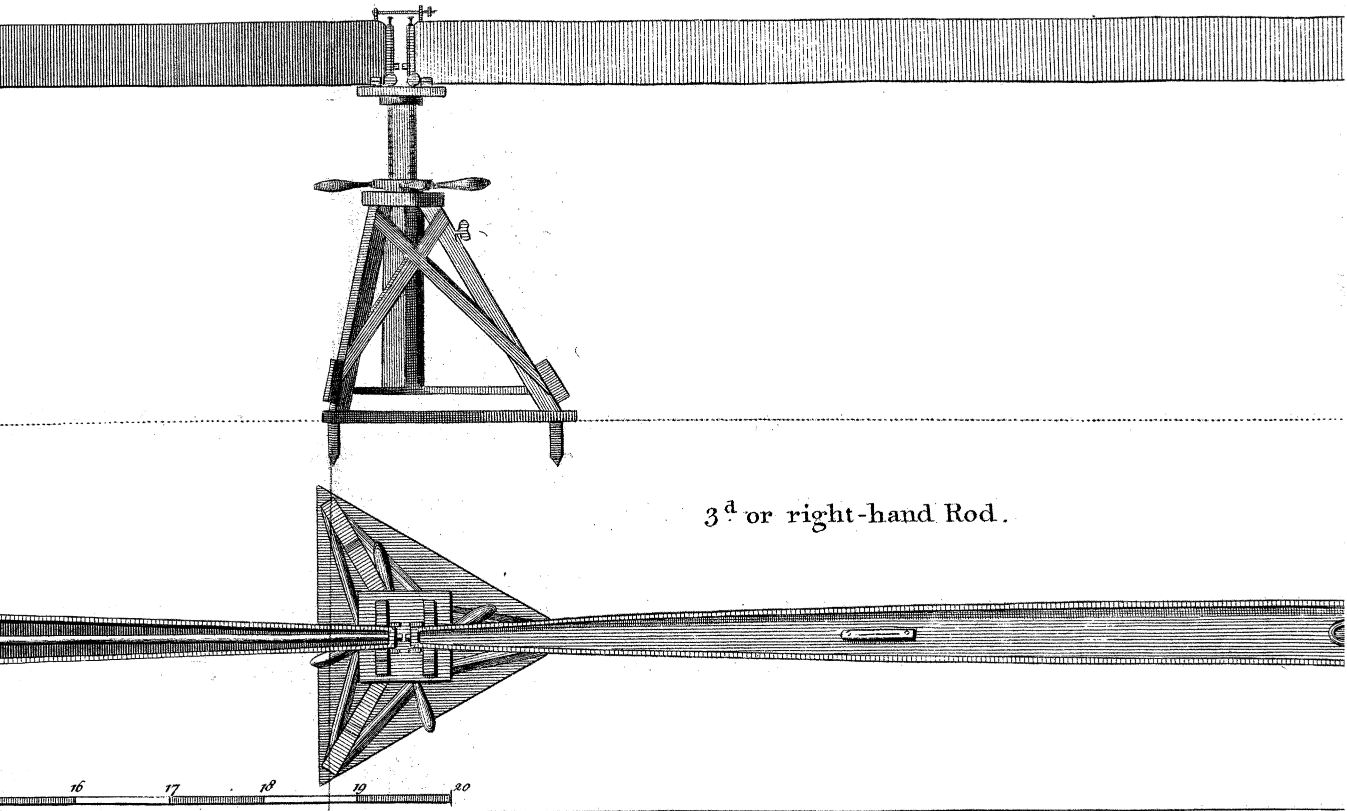


Scale of Inches for parts repreſented in 1/4 of their real dimenſions.



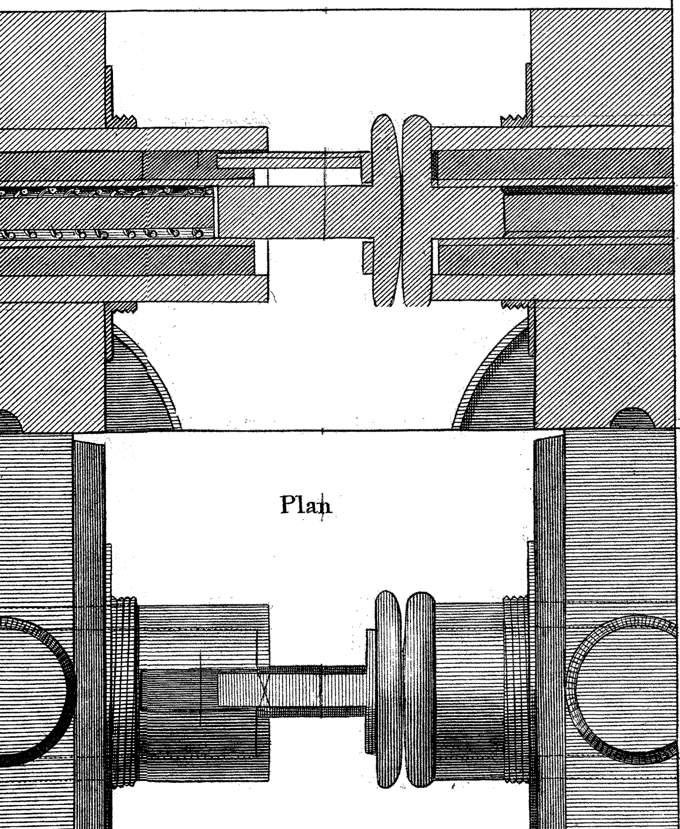
Longitudinal Section of the moveable
their real dimenſions.



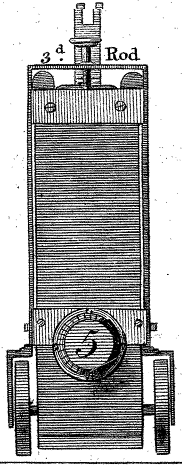


3^{d} or right-hand Rod.

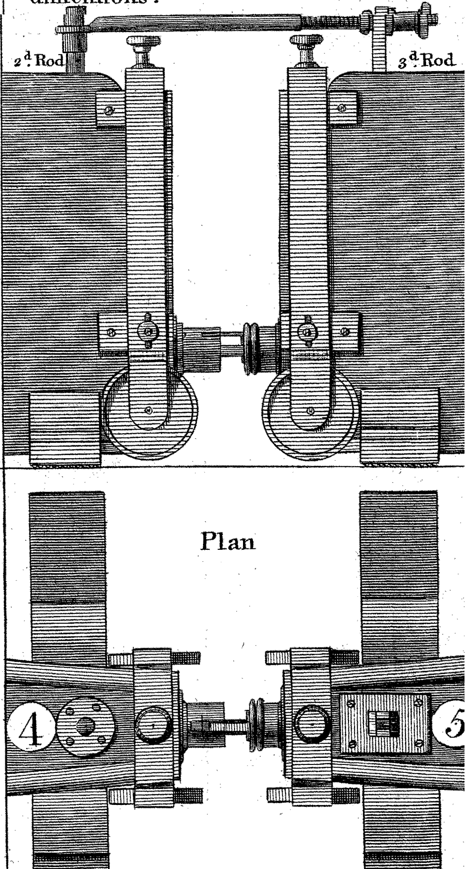
oveable End of the 2^{d} Rod and fixed End of the 3^{d} Rod in



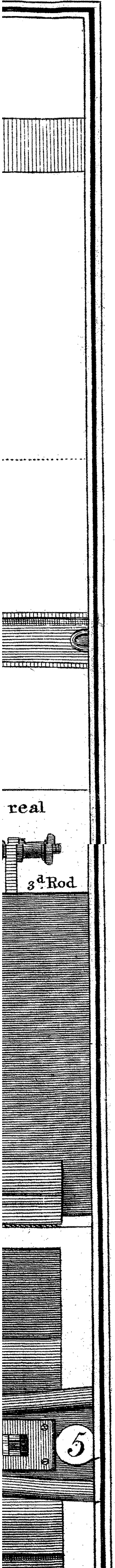
Front Elevation of the fixed End.

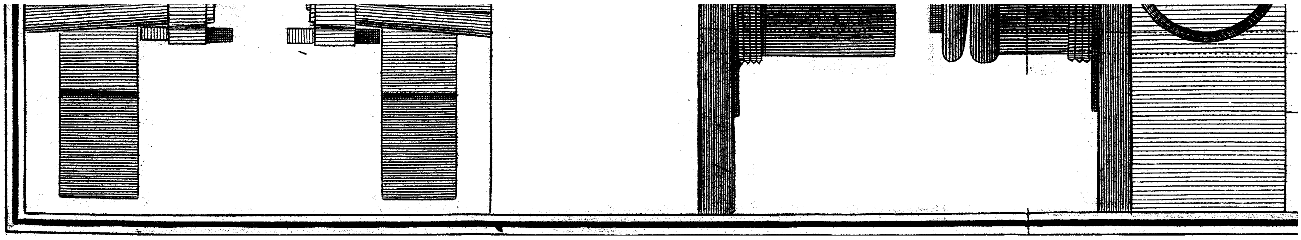


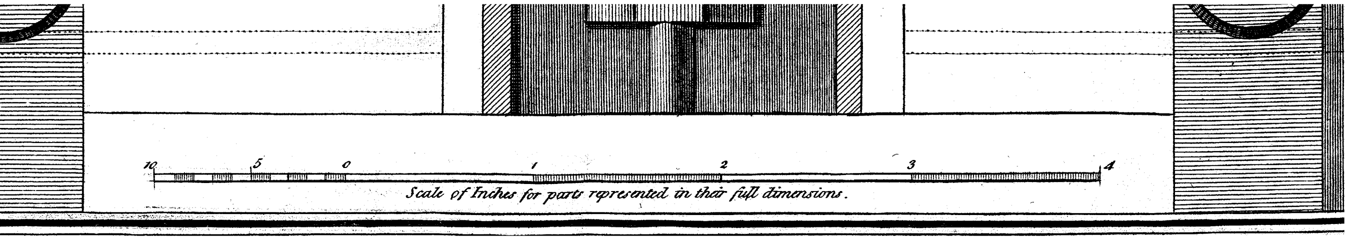
Longitudinal Elevation $\frac{1}{4}$ of the real dimensions.

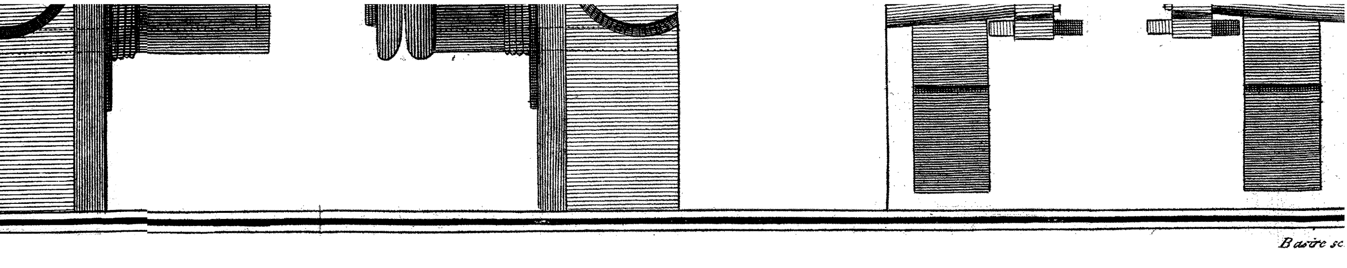


p. 480.

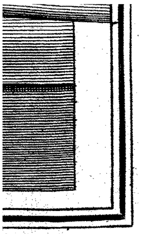





Scale of Inches for parts represented in their full dimensions.



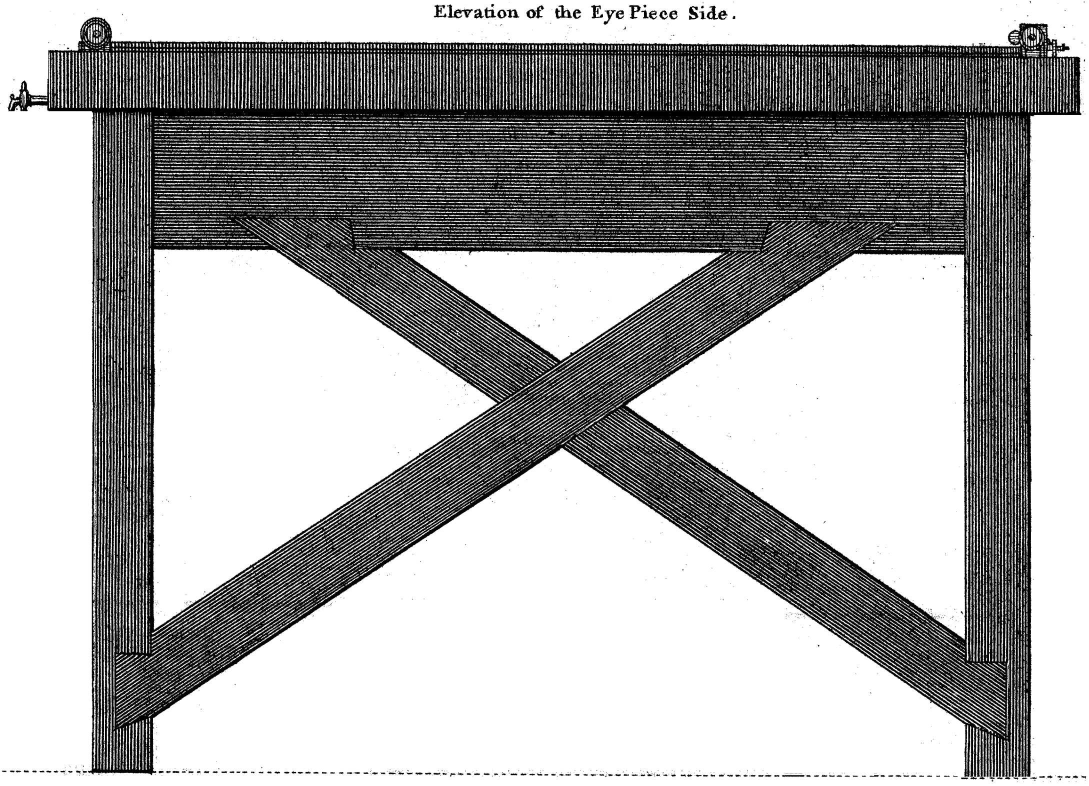
Basire sc

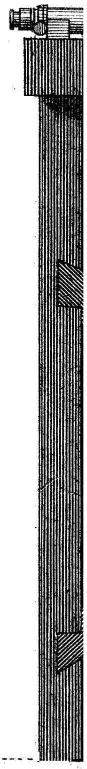


Basire sc.

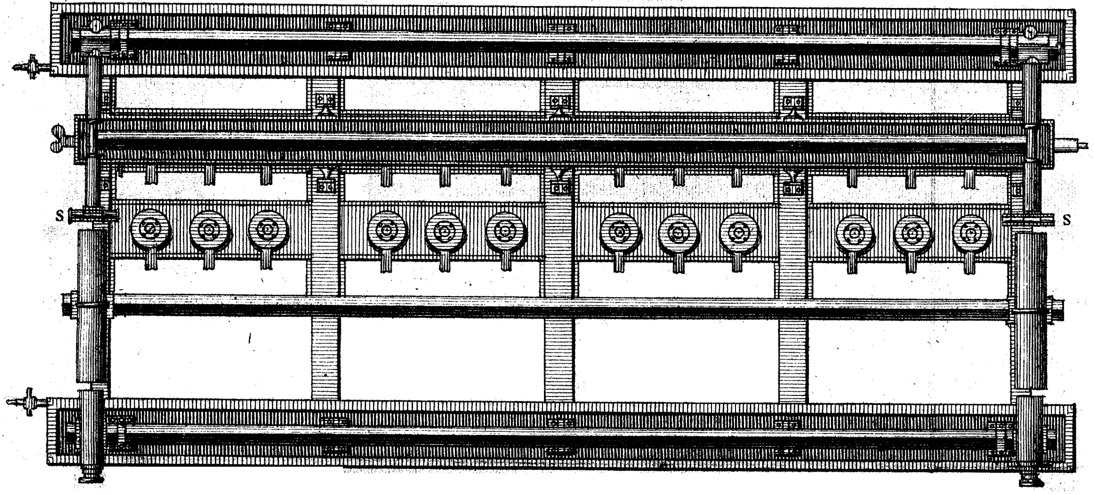
Fo

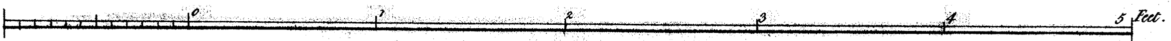
Elevation of the Eye Piece Side.



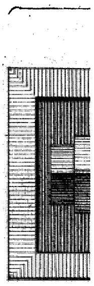


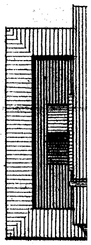
General Plan of the Top.



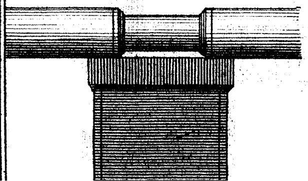


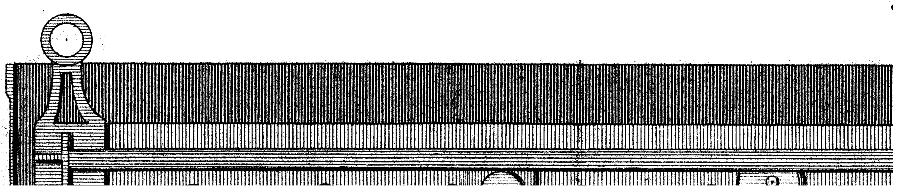
Scale to the General Plan and Elevations.



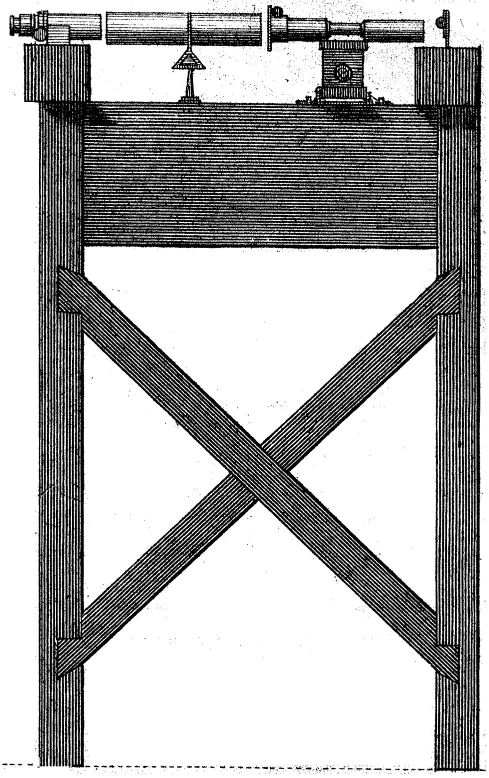


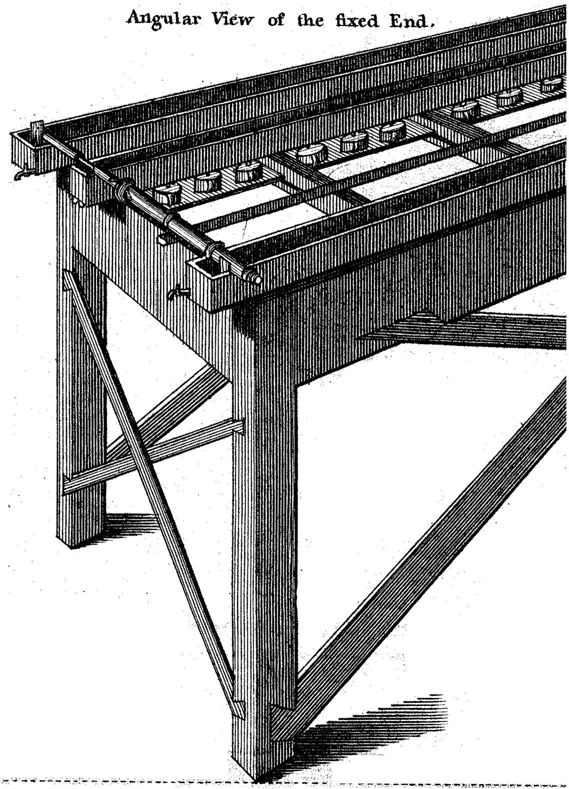
Elevation of the fixed end of the Boiler.

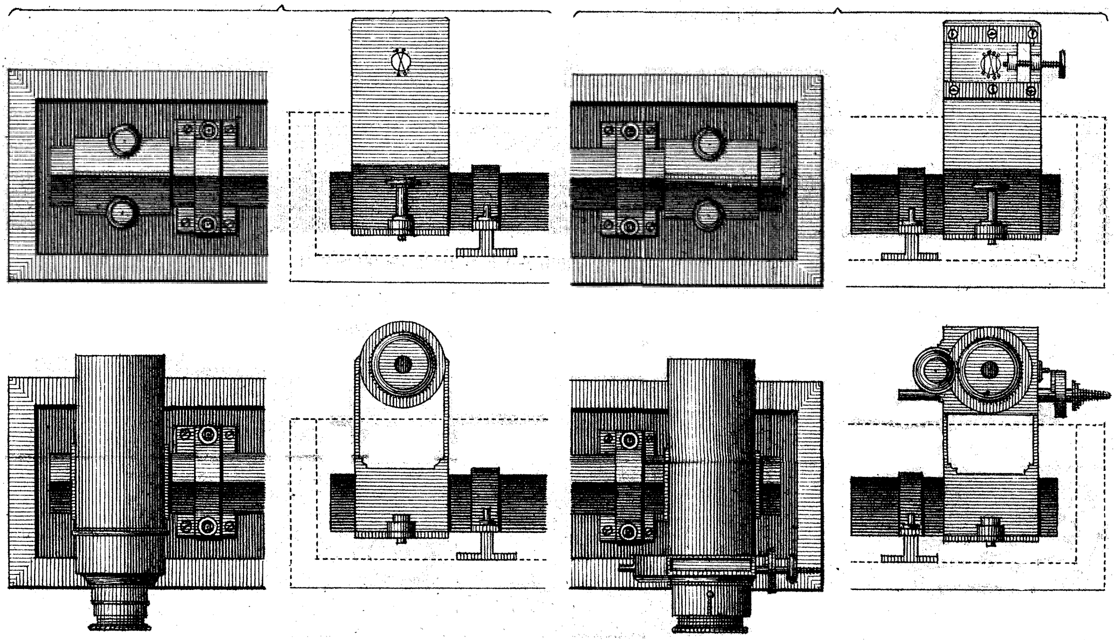




For the DESCRIPTION *and* USE *of the* MICROSCOPIC PYROMETER.

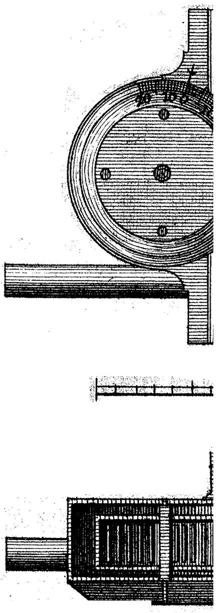

Elevation of the Micrometer End.

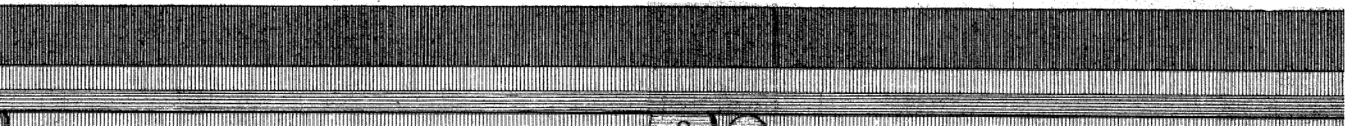

Angular View of the fixed End.


PLANS and ELEVATIONS of the MARKS and EYE-PIECES $\frac{1}{4}$ of the real size.

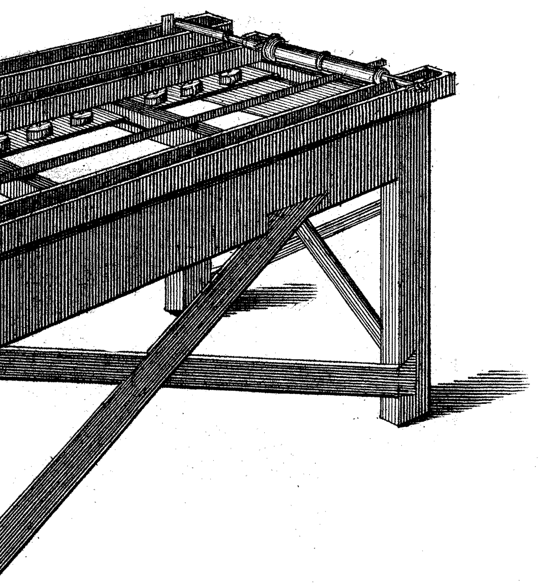
Fixed Microſcope.

Micrometer Microſcope

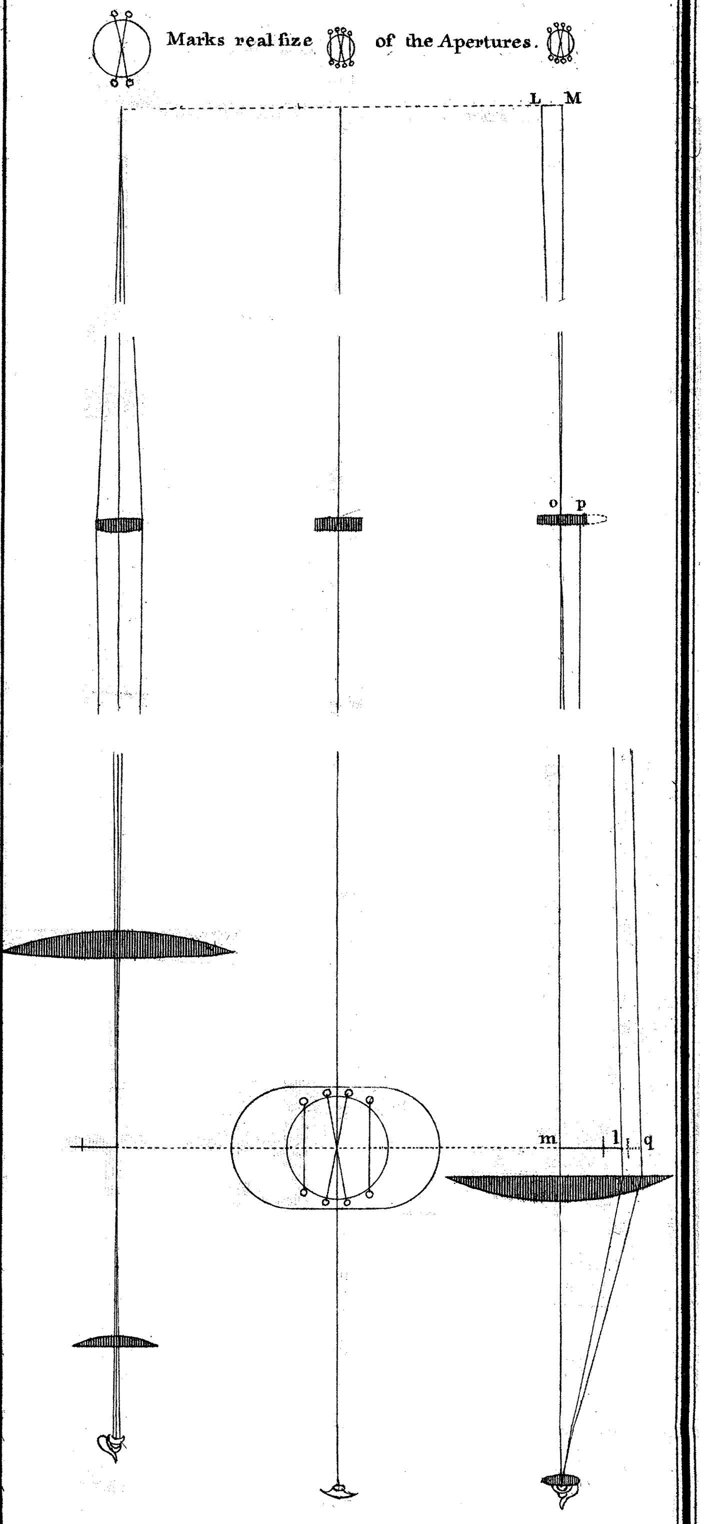



Longitudinal Section of the Boiler with its Slides and the Steel Rod as in experiment $\frac{1}{4}$ of the real size

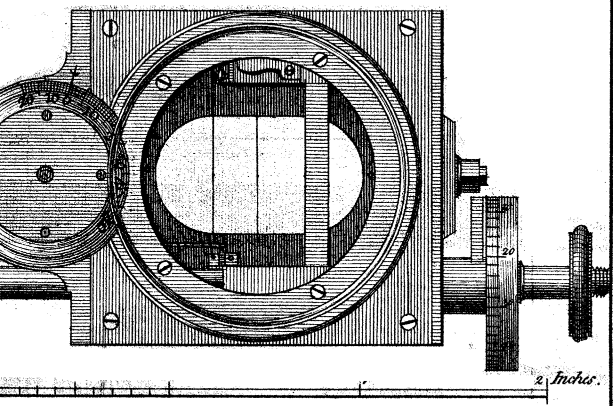
2.



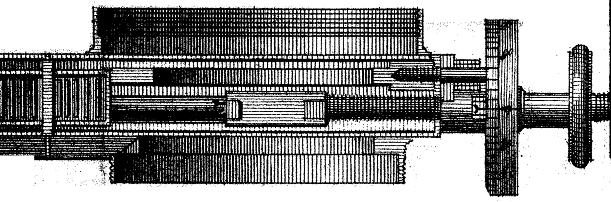
CONSTRUCTION of the MICROSCOPES.



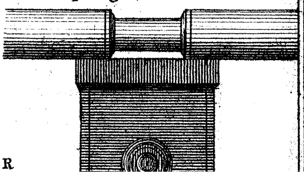
Elevation of the Micrometer full size.

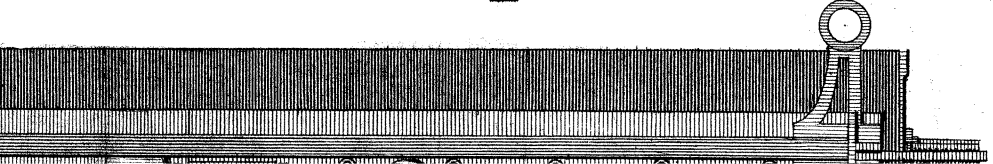


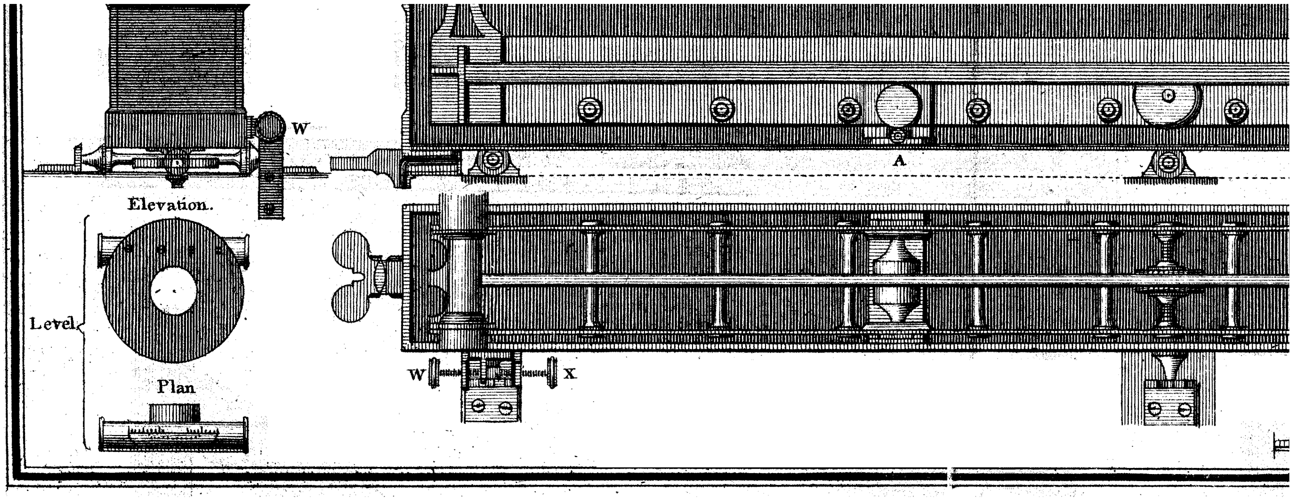
Horizontal Section of the Micrometer.

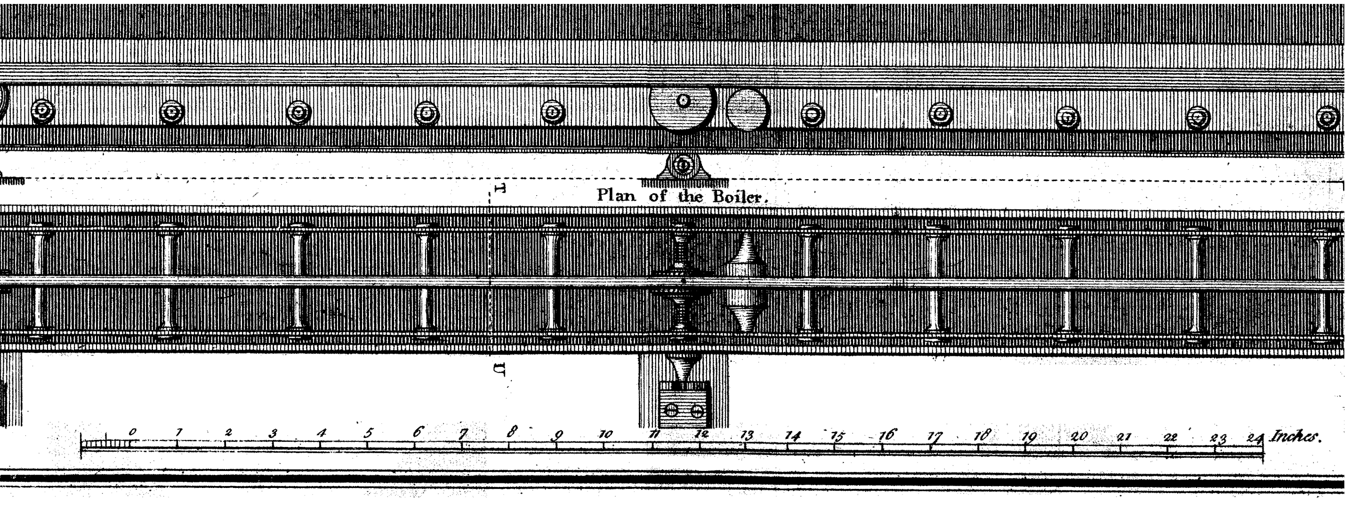


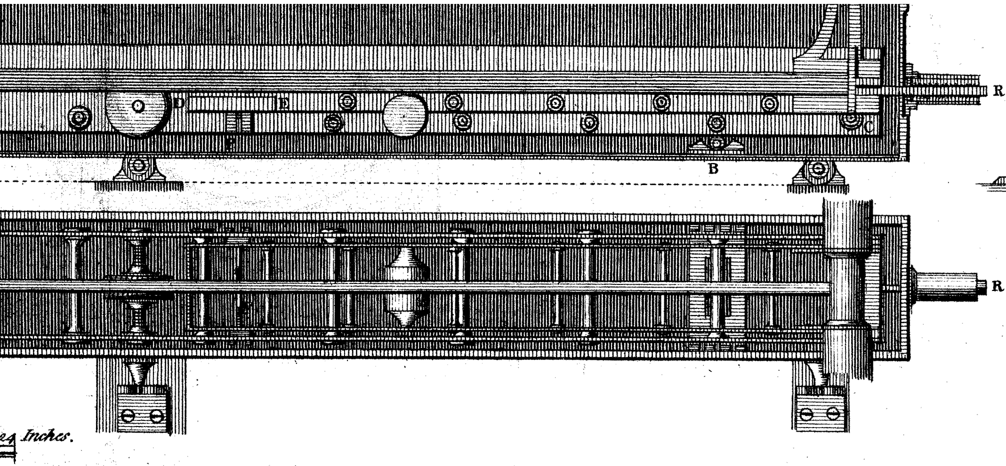
Elevation of the Spring End of the Boiler.

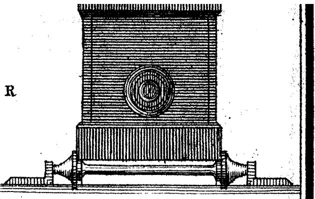


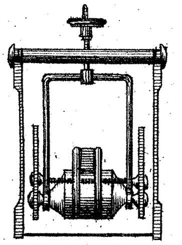



W
Elevation.
Level
Plan
A
W
X


Plan of the Boiler.




Section on the Line T.U.



Basire sc.

General Table of the Baſe, ſhewing the relative heights of the Stations above the ſouth-eaſt extremity near Hampton Poor-houſe, the Reduction of the Hypothenuſes, and the Correction for the Temperature of the Glaſs Rods; whence the true length is obtained in the heat of 62°.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sections.	N° of hypothenuſes, 600 feet each.	Relative heights.				Reduction of the hypothenuſes.	Number of rods, twenty feet each.	Temperature.		Correction for temperature.			Correct length of the baſe.
		Aſcent.	Deſcent.	Total aſcent.				Obſerved mean of 60 therm.	Exceſs or defect from 62°.	Expanſion above 62° + appt. leng.	Contract. below 62° — appt. leng.	Difference.	
				Hypoth.	Sections.								
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.		°	°	Inches.	Inches.	inches.	Feet.
Firſt or ſouth-eaſt ſection, between Hampton Poor-houſe and Hanworth Summer-houſe.	1	0.07	– –	0.07		0.000012	29+.925521	71.4	+ 9.4	+0.2909			
	2	1.855	– –	1.925		0.002875	30	80.7	+18.7	+0.5801			
	3	– –	1.855	0.07		0.002875	30	80.6	+18.6	+0.5770			
	4	2.745	– –	2.815		0.006288	30	74.0	+12.0	+0.3722			
	5	2.92	– –	5.735		0 007114	30	62 6	+ 0.6	+0.0186			
	6	0.76	– –	6.495		0.000489	30	58.7	– 3.3		–0.1024		
	7	1.57	– –	8.065		*0.000825	30	60.5	– 1.5		–0.0465		
	8	2.91	– –	10.975		0.007065	30	63.3	+ 1.3	+0.0403			
	9	– –	0.68	10.295		0.000393	30	64.1	+ 2.1	+0.0651			
	10	0.65	– –	10.945		0.000360	30	66.6	+ 4.6	+0.1427			
	11	– –	0.04	10.905		0.000009	30	70.4	+ 8.4	+0.2606			
	12	– –	1.18	9.725		0.001168	30	69.9	+ 7.9	+0.2451			
	13	0.83	– –	10.555	10.555	0.000581	30	62.7	+ 0.7	+0.0217			
Second or middle ſection, between Hanworth Summer-houſe and the north ſide of the Staines Road.	14	– –	0.94	9.615		0.000745	30	60.7	– 1.3		–0.0403		
	15	0.42	– –	10.035		0.000191	30	63.2	+ 1.2	+0.0372			
	16	– –	1.63	8.405		0.002222	30	69.0	+ 7.0	+0.2171			
	17	0.28	– –	8.685		0.000073	30	71.1	+ 9.1	+0.2823			
	18	4 16	– –	12.845		0.014439	30	68.6	+ 6.6	+0.2047			
	19	– –	0.44	12.405		0.000169	30	63.5	+ 1.5	+0.0465			
	20	0.19	– –	12.595		0.000036	30	59.2	– 2.8		–0.0869		
	21	1.87	– –	14 465		0.002922	30	56.2	– 5.8		–0.1799		
	22	0.73	– –	15.195		0.000452	30	57.0	– 5.0		–0.1551		
	23	0.39	– –	15 585		0.000135	30	64.1	+ 2.1	+0.0651			
	24	0.95	– –	16.535		0.000760	30	64.3	+ 2.3	+0.0713			
	25	0.49	– –	17.025		0.000208	30	62.5	+ 0.5	+0.0155			
	26	2.11	– –	19.135	8.58	*0.000063	30	71.1	+ 9.1	+0.2823			
Third or north-weſt ſection, between the north ſide of the Staines Road, and King's Arbour near the Colnbrook Road.	27	– –	0.71	18.425		*0.000214	30	70.5	+ 8.5	+0.2637			
	28	0.245	– –	18.67		0.000057	30	63.3	+ 1.3	+0.0403			
	29	1.21	– –	19.88		0.001228	30	59.2	– 2.8		–0.0869		
	30	– –	0.165	19.715		0.000028	30	66.2	+ 4.2	+0.1303			
	31	0.14	– –	19.855		0.000024	30	73.8	+11.8	+0.3660			
	32	– –	0.12	19 735		0.000019	30	77.6	+15.6	+0.4839			
	33	– –	0.14	19.595		0.000024	30	73.7	+11.7	+0.3629			
	34	1.21	– –	20.805		0.001228	30	68.8	+ 6.8	+0.2109			
	35	1.405	– –	22.21		0.001653	30	65.8	+ 3.8	+0.1179			
	36	2.34	– –	24.55		0.004571	30	65.5	+ 3.5	+0.1086			
	37	– –	1.085	23.465		0.000985	30	61.5	– 0.5		–0.0155		
	38	0.47	– –	23.935		0.000192	30	59.4	– 2.6		–0.0807		
	39	0.525	– –	24.46		0.000238	30	55.6	– 6.4		–0.1985		
	40	1.265	– –	25.725		0.001341	30	55.1	– 6.9		–0.2140		
	41	1.18	– –	26.905		0.001168	30	56.1	– 5.9		–0.1830		
	42	– –	0.19	26.715		0.000036	30	58.4	– 3.6		–0.1117		
	43	1.565	– –	28.28		0.002049	30	58.2	– 3.8		–0.1179		
	44	1.485	– –	29.765		0.001845	30	57.3	– 4.7		–0.1458		
	45	0.24	– –	30.005		0.000055	30	60.8	– 1.2		–0.0372		
	46	1.26	– –	31.265	12.130	0.001973	20	65.3	+ 3.3	+0.0682			
	400 ft.												
		40.44	9.175	31.265	31.265	0.071401	1369+.925521			+5.9890	– 1.8023	+4.1867	

Hypothenuſal length of the baſe containing 1369.925521 glaſs rods of twenty feet each + 4.31 feet, - - -	=	27402.8204
Reduction contained in the ſeventh column to be ſubtracted, - - - - - -	–	0.0714
Total apparent length of the baſe reduced to the level of the ſouth-eaſt extremity, - - - -		27402.7490
Add to the apparent length the difference between the expanſion of glaſs above, and the contraction of it below 62°, contained in the thirteenth column = 4.1867 inches = - - - - - - -	+	0.3489
Add further to the apparent length the equation for 6° difference of temperature of the ſtandard braſs ſcale between 62° and 68°, the heat in which the glaſs rods were laid off = 20.3352 inches, = - - - - - -	+	1.6946
Correct length of the baſe in the temperature of 62°, reduced to the level of the lowermoſt extremity, - -	=	27404.7925
Reduction for the height of the lower end of the baſe above the mean level of the ſea, ſuppoſed to be 54 feet or 9 fathoms =	–	0.0706
True length of the baſe reduced to the mean level of the ſea, - - - - - -	=	27404.7219

Table of the Expanſions of Metals, deduced from experiments made with the Microſcopic Pyrometer in April 1785.

Deſcription of the Metal Rods put to experiment.		Revolutions and parts of the micrometer for the expanſion on five feet.		Actual expanſion in parts of an inch by 180°, the revolutions being divided by 32.06.			By 1° of FAHRENHEIT the expanſion is						Baſes of 27400 feet of theſe metals would expand.			
		By 180°	By 1°.	On 5 feet.	On 1 foot.	On 100 ft.	On 1 foot.	10 feet.	100 feet.	400 feet.	600 feet.	1000 ft.	By 1°.	By 10°.	By 20°.	By 30°.
		Rev.Pts.	Parts.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Standard braſs ſcale.	Suppoſed to be Hamburgh plate braſs; length 42.187 inches, or 3.568 feet; breadth 0.55 inch; thickneſs 0.25 inch; and weight 1 lb. 10½ oz. Its expanſion was meaſured by 25.47 revolutions of the micrometer; wherefore that on five feet would have been meaſured by -	35.69	19.$\frac{83}{100}$	0.111323	0.0222646	2.22646	0.0001237	0.001237	0.01237	0.04948	0.07422	0.1237	3.38938	33.8938	67.7876	101.6814
Engliſh plate braſs, in form of a rod.	Length five feet; breadth 0.9 inch; thickneſs 0.15 inch; and weight 2 lbs. 5½ oz. Difficult from its thinneſs to be kept free from warping, - - -	36.41	20.$\frac{23}{100}$	0.113568	0.0227136	2.27136	0.0001262	0.001262	0.01262	0.05048	0.07572	0.1262	3.45788	34.5788	69.1576	103.7364
Engliſh plate braſs, in form of a trough.	Length five feet; breadth 1.4 inch; depth 1 inch; weight 8 lbs. 3 oz. Perfectly ſtrong and ſtraight, - - -	36.45	20.$\frac{25}{100}$	0.113693	0.0227386	2.27386	0.0001263	0.001263	0.01263	0.05052	0.07578	0.1263	3.46062	34.6062	69.2124	103.8168
Steel rod.	Length five feet; breadth 0.5 inch; thickneſs 0.3 inch; weight 2 lbs. 7½ oz. Made from the very ſame bar with the chain, - -	22.02	12.$\frac{23}{100}$	0.068684	0.0137368	1.37368	0.0000763	0.000763	0.00763	0.03052	0.04578	0.0763	2.09062	20.9062	41.8124	62.7186
Caſt iron priſm.	Length five feet; each of its ſides 1¼ inch; and weight 11 lbs. 9 oz Cut from the ſame rod with the ſtandard priſms of the pyrometer,	21.34	11.$\frac{86}{100}$	0.066563	0.0133126	1.33126	0.0000740	0.000740	0.00740	0.02960	0.04440	0.0740	2.02760	20.2760	40.5520	60.8280
Glaſs tube.	Length five feet; $\frac{3}{10}$ths inch diameter; weight 1 lb. 13½ oz. Drawn from the ſame pot of metal with the meaſuring rods, -	14.93	8.$\frac{29}{100}$	0.046569	0.0093138	0.93138	0.0000517	0.000517	0.00517	0.02068	0.03102	0.0517	1.41658	14.1658	28.3316	42.4974
Solid glaſs rod.	Length 40.44 inches, or 3.37 feet; mean diameter ſix-tenths of an inch; and weight 1 lb. 2 oz. It had been applied for ſeveral years to a clock. Its expanſion was meaſured by 10.46 revolutions of the micrometer; wherefore that on five feet would have been meaſured by -	15.54	8.$\frac{63}{100}$	0.048472	0.0096944	0.96944	0.0000539	0.000539	0.00539	0.02156	0.03234	0.0539	1.47686	14.7686	29.5372	44.3058

PLAN ſhewing the ſituation of the BASE meaſured on HOUNSLOW HEATH in Summer 1784.

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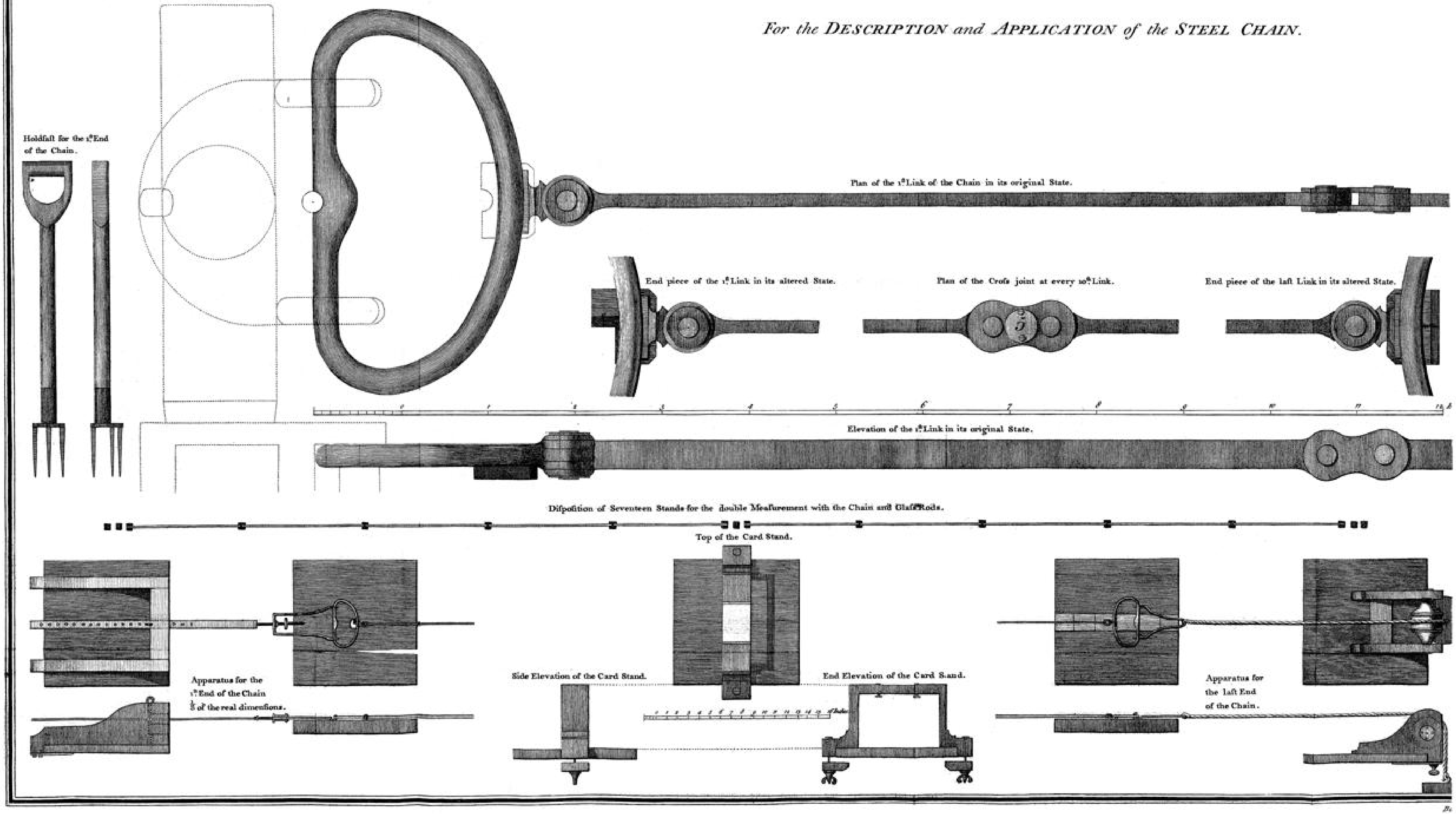
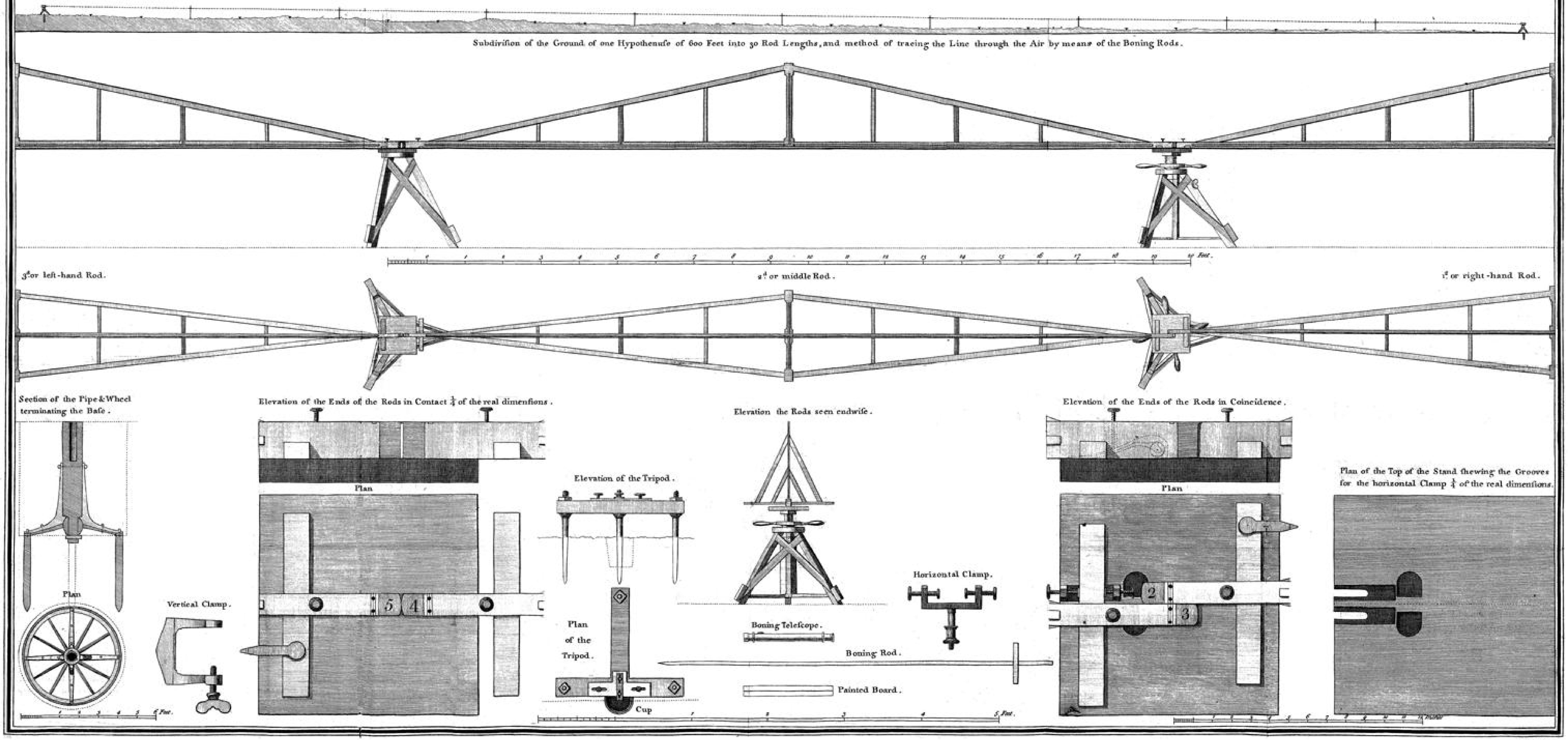
For the DESCRIPTION *and* APPLICATION *of the* STEEL CHAIN.

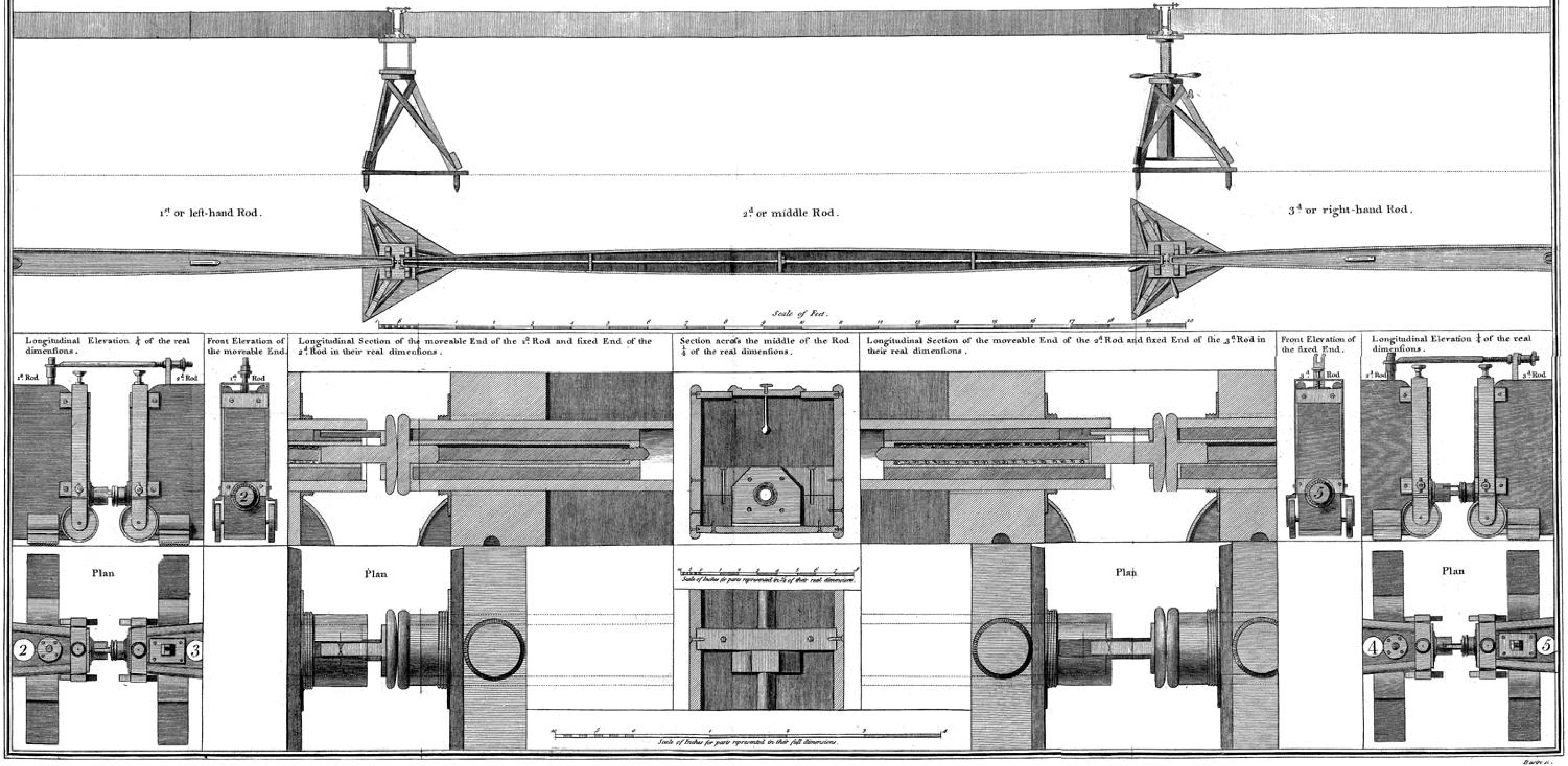

Holdfaſt for the 1st End of the Chain.
Plan of the 1st Link of the Chain in its original State.
End piece of the 1st Link in its altered State.
Plan of the Croſs joint at every 10th Link.
5
End piece of the laſt Link in its altered State.
0 1 2 3 4 5 6 7 8 9 10 11 12
Elevation of the 1st Link in its original State.
Diſpoſition of Seventeen Stands for the double Meaſurement with the Chain and Glaſs Rods.
Top of the Card Stand.
Apparatus for the 1st End of the Chain
1/5 of the real dimenſions.
Side Elevation of the Card Stand.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 of Inches
End Elevation of the Card Stand.
Apparatus for the laſt End of the Chain.

For the DESCRIPTION and APPLICATION of the DEAL RODS &c.


Subdiviſion of the Ground of one Hypothenuſe of 600 Feet into 30 Rod Lengths, and method of tracing the Line through the Air by means of the Boning Rods.
20 Feet.
3d or left-hand Rod.
2d or middle Rod.
1st or right-hand Rod.
Section of the Pipe & Wheel terminating the Baſe.
Plan
6 Feet.
Vertical Clamp.
Elevation of the Ends of the Rods in Contact 1/4 of the real dimenſions.
Plan
5
4
Elevation of the Tripod.
Plan of the Tripod.
Cup
5 Feet.
Elevation the Rods seen endwiſe.
Boning Teleſcope.
Boning Rod.
Painted Board.
Horizontal Clamp.
Elevation of the Ends of the Rods in Coincidence.
Plan
2
3
Plan of the Top of the Stand ſhewing the Grooves for the horizontal Clamp 1/4 of the real dimenſions.

Basire sc.

For the DESCRIPTION *and* APPLICATION *of the* GLASS RODS.



Longitudinal Elevation ¼ of the real dimenſions.

Front Elevation of the moveable End.

Longitudinal Section of the moveable End of the 1st Rod and fixed End of the 2d Rod in their real dimenſions.

Section acroſs the middle of the Rod ¼ of the real dimenſions.

Longitudinal Section of the moveable End of the 2d Rod and fixed End of the 3d Rod in their real dimenſions.

Front Elevation of the fixed End.

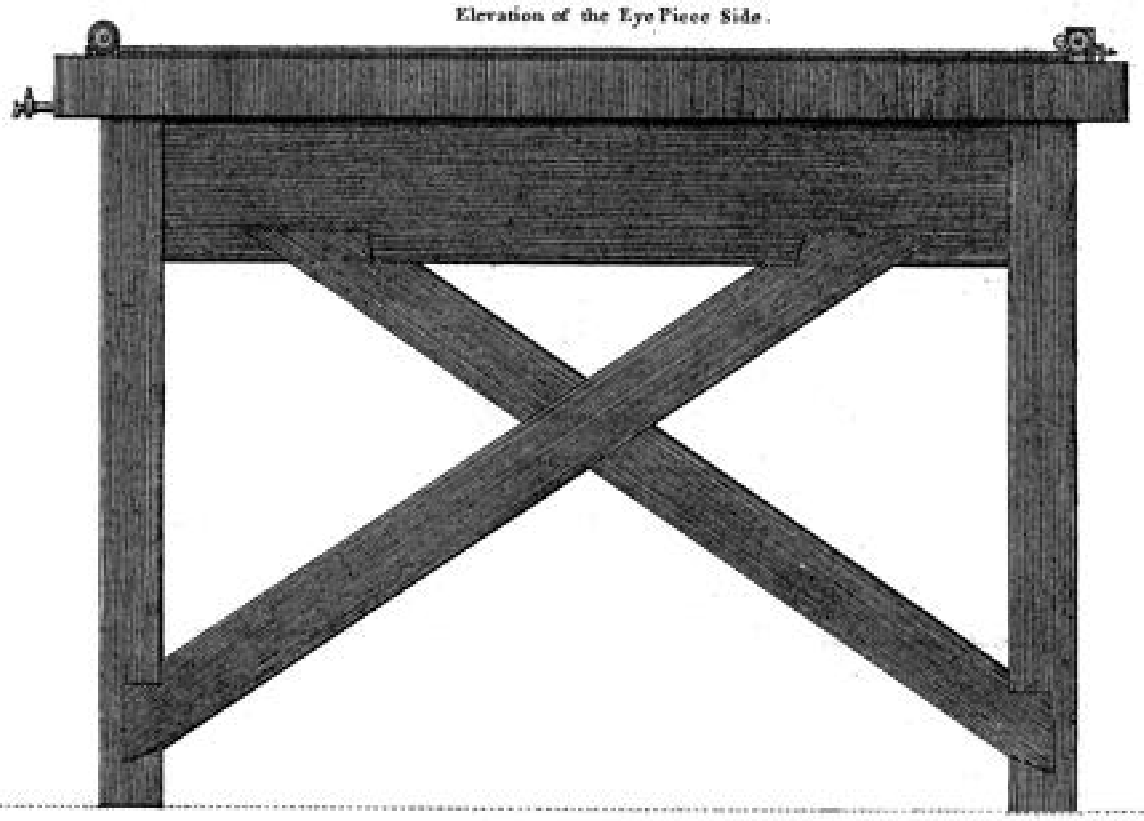
Longitudinal Elevation ¼ of the real dimenſions.

1st or left-hand Rod.
2d or middle Rod.
3d or right-hand Rod.
Scale of Feet.
1st Rod
2d Rod
1st Rod
2
3d Rod
5
2d Rod
3d Rod
Plan
2
3
Plan
Scale of Inches for parts represented in ¼ of their real dimensions.
Plan
Plan
4
5
Scale of Inches for parts represented in their full dimensions.

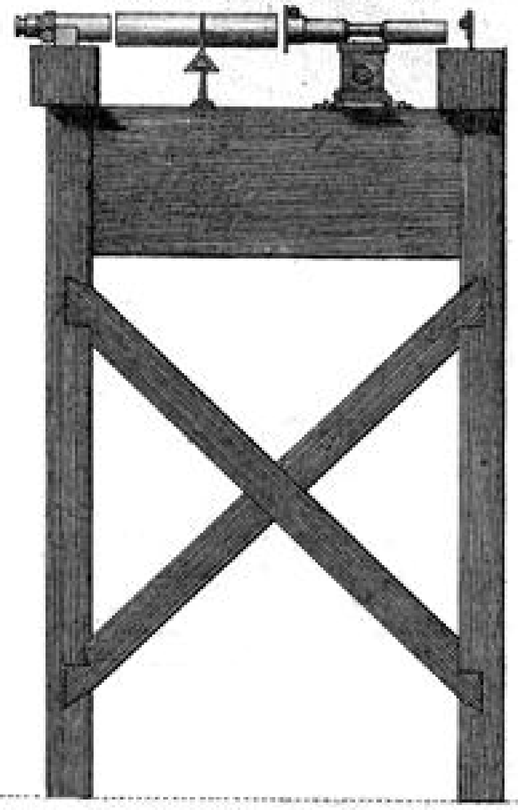
Basire sc.

For the DESCRIPTION and USE of the MICROSCOPIC PYROMETER.

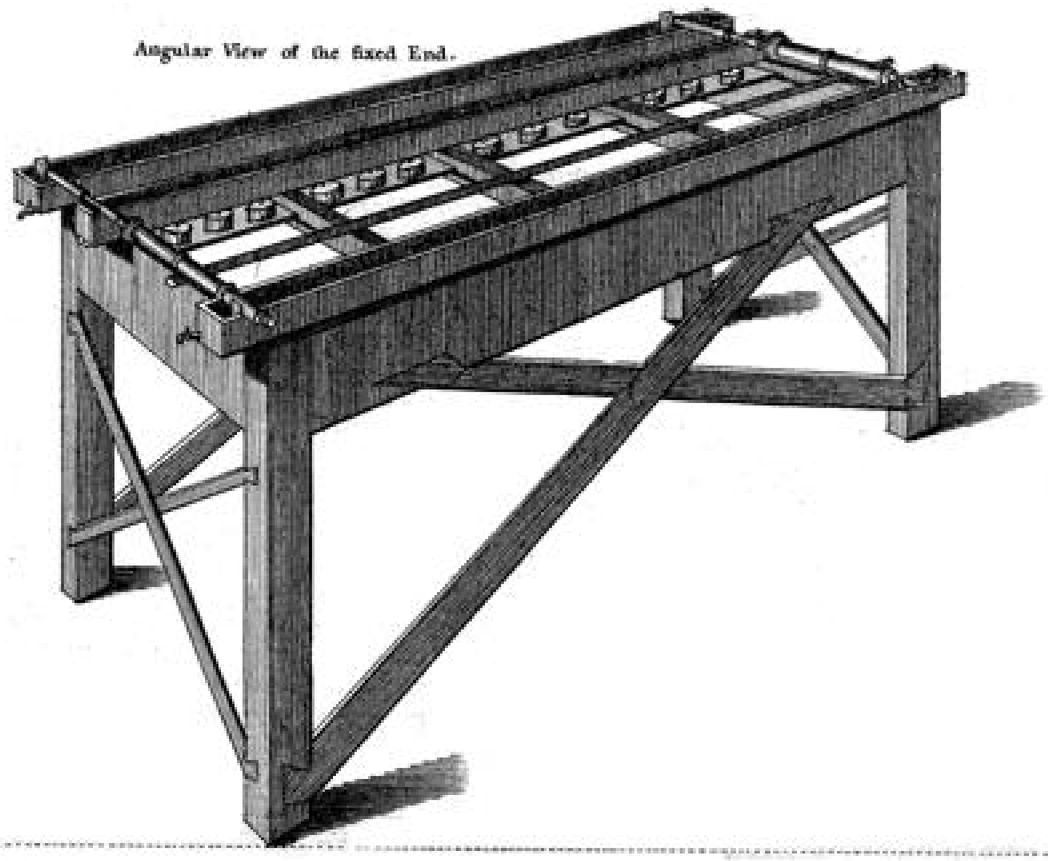
Elevation of the Eye Piece Side.



Elevation of the Micrometer End.

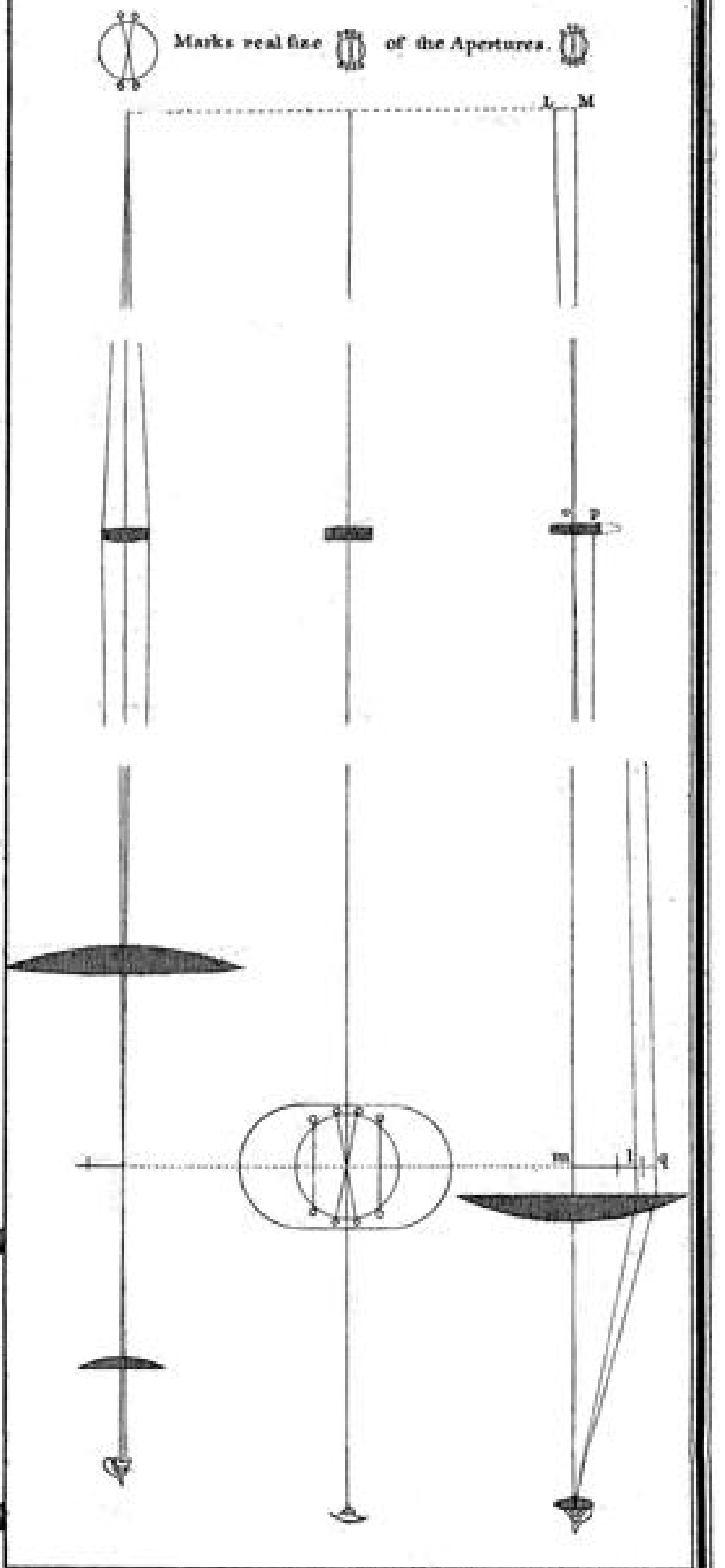


Angular View of the fixed End.

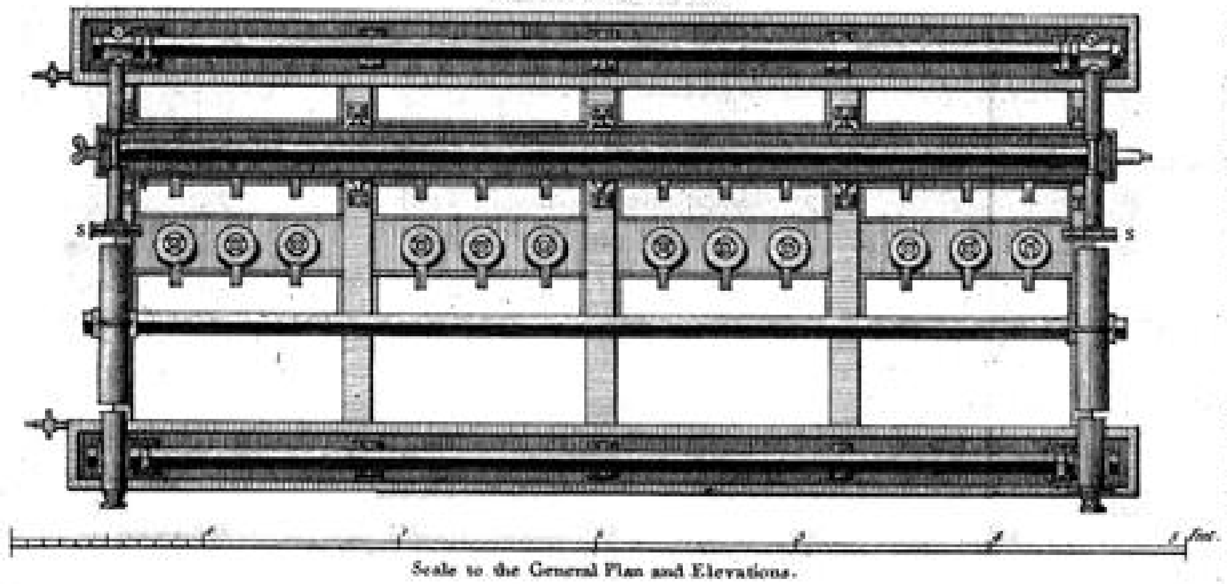


CONSTRUCTION of the MICROSCOPES.

Marks real size of the Apertures.

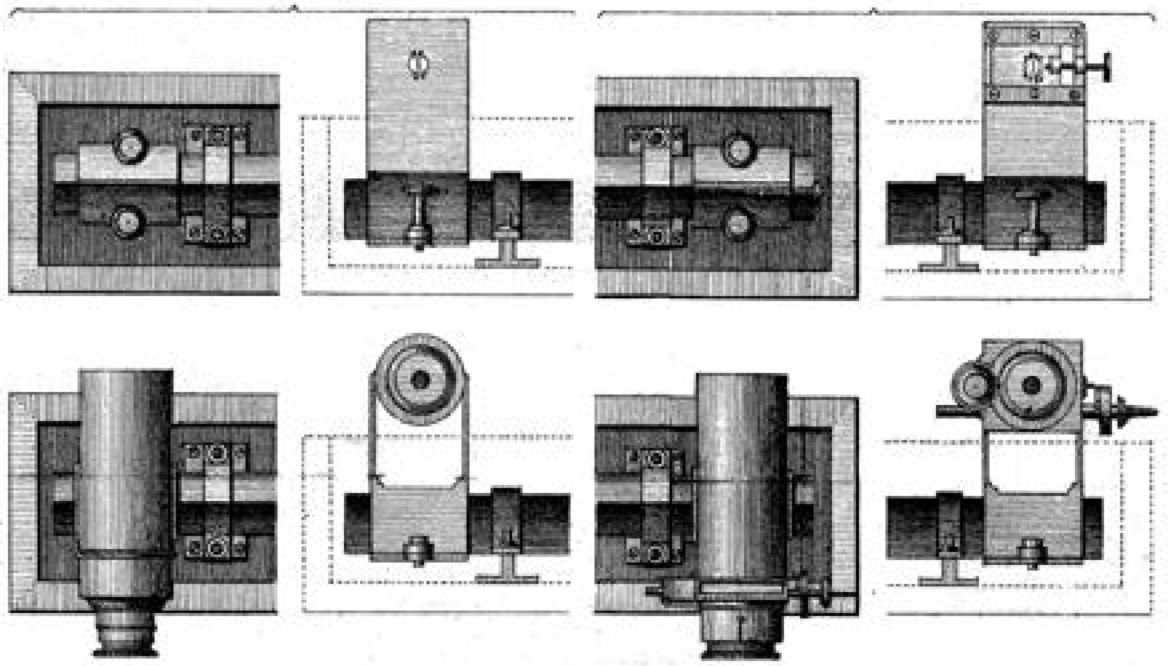


General Plan of the Top.



Scale to the General Plan and Elevations.

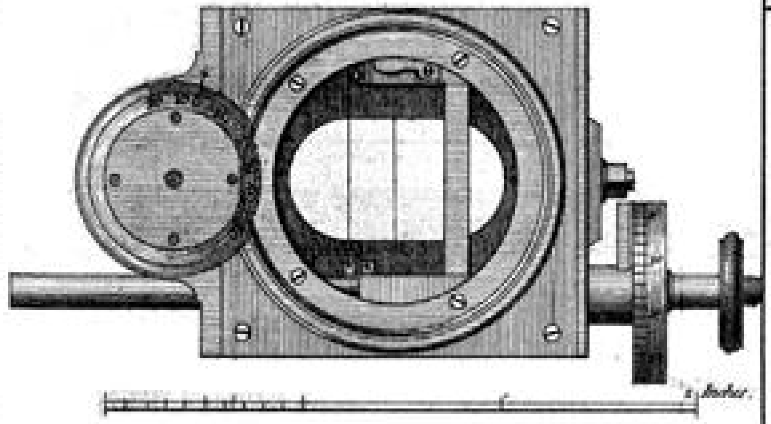
PLANS and ELEVATIONS of the MARKS and EYE-PIECES ½ of the real size.



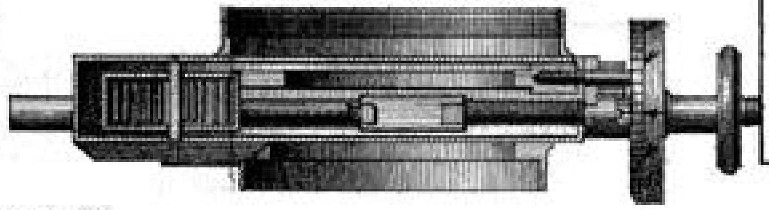
Fixed Microscope.

Micrometer Microscope

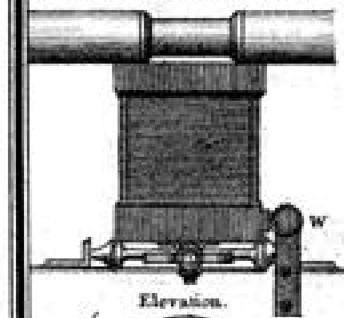
Elevation of the Micrometer full size.

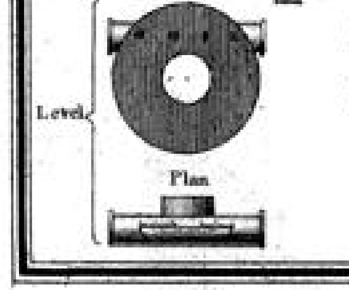


Horizontal Section of the Micrometer.

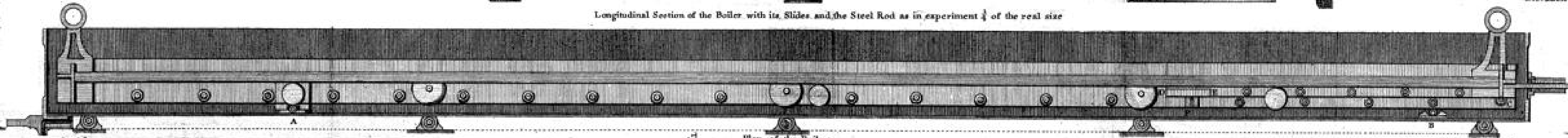


Elevation of the fixed end of the Boiler.

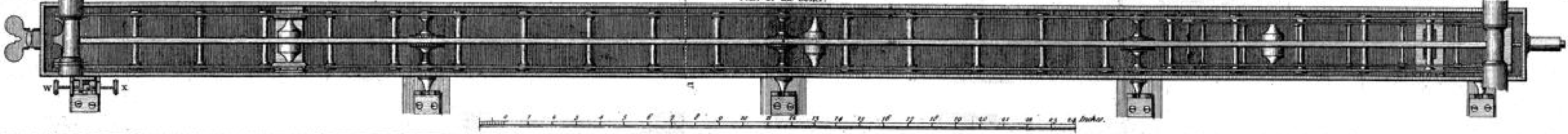




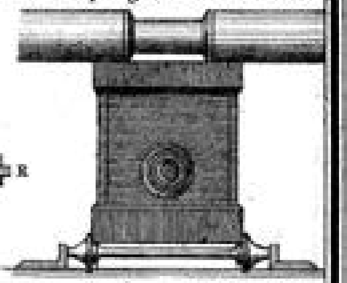
Longitudinal Section of the Boiler with its Slides and the Steel Rod as in experiment ¼ of the real size



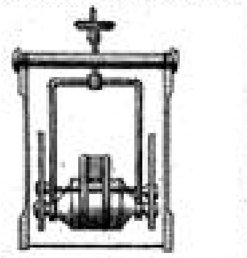
Plan of the Boiler.



Elevation of the Spring End of the Boiler.



Section on the Line T.U.



Basire sc.